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LOOKING AHEAD

Unless otherwise indicated, all events take place in London. B.C.A.C., British Conference on Automation and Computation. B.C.S., British Computer Society. Brit.I.R.E., British Institution of Radio Engineers. I.C.E., Institution of Civil Engineers. I.Chem.E., Institution of Chemical Engineers. I.E.E., Institution of Electrical Engineers. I.Mech.E., Institution of Mechanical Engineers. I.Prod.E., Institution of Production Engineers. I.S.A., Instrument Society of America. R.Ae.S., Royal Aeronautical Society. S.B.A.C., Society of British Aircraft Constructors. S.I.T., Society of Instrument Technology.

MONDAY 13 NOVEMBER
Lecture on *Data transmission* by R. H. Franklin and J. Rhodes. 7 p.m. Duncan Hall, Stone, Staffs. (*I.E.E.*)

Informal paper on *Numerical control of machine tools* by D. F. Walker. 7 p.m. Royal College of Science and Technology, Glasgow. (*I.E.E.*)

The role of the physicist in process control by Dr L. J. R. Postle. 6.15 p.m. Manchester University. Details: The Institute of Physics and The Physical Society, 47 Belgrave Sq., London, S.W.1.

MONDAY 13—SATURDAY 18 NOVEMBER
Second Engineering Materials and Design Exhibition and Conference. Earls Court. Details: J. Brewster, Commonwealth Ho., New Oxford St, W.C.1.

International Factory Equipment Exhibition. Earls Court. Details: J. Brewster, Commonwealth Ho., New Oxford St, W.C.1.

TUESDAY 14 NOVEMBER
High-speed ferrite cores by P. Cooke. 6 p.m. Southampton University. (*I.E.E.*)

Informal paper on *Numerical control of machine tools* by D. F. Walker. 7 p.m. Carlton Hotel, Edinburgh. (*I.E.E.*)

WEDNESDAY 15 NOVEMBER
Some aspects of the design of machine tools and automation equipment for the future by F. A. Lewis. 7 p.m. James Watt Memorial Institute, Birmingham. (*I.Prod.E.*)

Introduction to analogue computers by H. Davies. 7 p.m. Bristol College of Science and Technology. (*Brit.I.R.E.*)

THURSDAY 16 NOVEMBER
Digital techniques for the study of sea waves, ship motion, and similar processes by D. E. Cartwright, M. J. Tucker and Miss D. B. Catton. (*S.I.T.*)

MONDAY 20 NOVEMBER
Lecture on *Simulation of intelligence* by Prof. D. M. MacKay. 6.15 p.m. Rutherford College of Technology, Newcastle-upon-Tyne. (*I.E.E.*)

MONDAY 20—FRIDAY 24 NOVEMBER
Design Appreciation Courses for Engineers (Staff Course). Details: Press Office, Council of Industrial Design, 28 Haymarket, S.W.1.

(*See also Monday* 27 *November—Friday* 1 *December*).

TUESDAY 21 NOVEMBER
Static switching applied to machine-tool control by W. G. Turner. 7.30 p.m. Half-way House, Dunstable Road, Luton. (*I.Prod.E.*)

Lecture on *Transistor instrumentation in rockets* by G. G. Haigh. 6.15 p.m. Engineers Club, Albert Sq., Manchester. (*I.E.E.*)

WEDNESDAY 22 NOVEMBER
A symposium on *Materials in space technology*. The Lecture Theatre, R.Ae.S. Details: The British Interplanetary Society, 12 Bessborough Gdns, S.W.1.

Electronic analogue computer simulation of multi-machine power system networks by A. S. Alfred, and *Analysis of overall stability of multi-machine power systems* by J. G. Miles. (*I.E.E.*)

Symposium on *Adaptive optimizing control*. (*Brit.I.R.E.*)

MONDAY 27 NOVEMBER—FRIDAY 1 DECEMBER
Design Appreciation Courses for Engineers (Executives Course). Details: Press Office, Council of Industrial Design, 28 Haymarket, S.W.1.

TUESDAY 28 NOVEMBER
Automatic plant analysis by electrochemical methods by R. F. Rodger. (*S.I.T.*)

WEDNESDAY 29—THURSDAY 30 NOVEMBER
A conference on *Oil hydraulic power transmission and control*. (*I.Mech.E.*)

THURSDAY 30 NOVEMBER
Numerically controlled machine tools by R. C. Brewer. 7.30 p.m. Ruston Club, Lincoln. (*I.Prod.E.*)

THURSDAY 30 NOV.—FRIDAY 1 DEC.
A symposium on *Nuclear electronics*. (*I.E.E.*)

MONDAY 4 DECEMBER
Lecture on *The simulation of intelligence* by Prof. D. M. MacKay. 6.30 p.m. Royal Institution, Liverpool. (*I.E.E.*)

WEDNESDAY 6 DECEMBER
Transistors in computers and control equipment by P. James. 6.45 p.m. Leicester University. (*Brit.I.R.E.*)

THURSDAY 7 DECEMBER
A symposium on *The analysis of errors in analogue computation* directed by Dr R. Vichnevetsky, Bristol College of Science and Technology.

WEDNESDAY 13 DECEMBER
Application of complex plane methods to system design by P. K. M'Pherson. (*S.I.T.*)

Nuclear power-station instrumentation by M. W. Jervis. 7.30 p.m. The Walker Art Gallery, Liverpool. (*Brit.I.R.E.*)

Analysis of overall stability of multi-machine power systems by J. G. Miles. 6 p.m. Institution of Engineers and Shipbuilders, Elmbank Crescent, Glasgow. (*I.E.E.*)

TUESDAY 19 DECEMBER
Lecture on *The use of controllable semi-conductor rectifiers in machine control* by K. G. King. (*I.E.E.*)

JANUARY 1962
A new approach to corrosion instrumentation and control by C. Edelsamm. King's College, Newcastle-upon-Tyne. (*I.Chem.E.*)

TUESDAY 9 JANUARY 1962
Lecture on *A linear transducer of high accuracy* by P. C. F. Wolfendale. (*I.E.E.*)

TUESDAY 9—THURSDAY 11 JANUARY 1962
The 8th National Symposium on *Reliability and quality control in electronics*. Washington, D.C., U.S.A. Details: R. Brewer, Hirst Research Centre, G.E.C. Ltd, Wembley, Middx.

WEDNESDAY 10 JANUARY 1962
Automatic assessment of transistor life-test data by K. Walker and M. J. Crouch. 7 p.m. Southampton University. (*Brit.I.R.E.*)

Lecture on *Automatic control of machines for assembling mechanical components* by A. V. Hemingway and R. L. Dressler. 6.30 p.m. Brighton Technical College. (*I.E.E.*)

THURSDAY 11 JANUARY 1962
Digital telemetry by J. B. Richardson. 7 p.m. Royal Society of Arts. Details: The Radar and Electronics Association, 43 Grove Park Rd, Chiswick, W.4.

TUESDAY 16 JANUARY 1962
Lecture on *Automatic control of machines for assembling mechanical components by* A. V. Hemingway and R. L. Dressler. 6.15 p.m. Engineers Club, Albert Sq., Manchester. (*I.E.E.*)

WEDNESDAY 17 JANUARY 1962
Verdan—a miniature computer for airborne use by P. B. Rayner and S. Morleigh. (*Brit.I.R.E.*)

WEDNESDAY 17—THURSDAY 18 JANUARY 1962
A symposium on *Electronic aids to banking*, under the aegis of B.C.A.C. Details and registration forms: I.E.E.

MONDAY 22 JANUARY 1962
'Exposition meeting' on *Recent developments in automatic boiler control practice*. Details: R. J. Redding, 66 The Drive, Isleworth, Middx. (*See also Control, July, p.* 122). (*S.I.T.*)

TUESDAY 23 JANUARY 1962
Lecture on *Power supply control systems* by P. F. Gunning. (*I.E.E.*)

FRIDAY 16—TUESDAY 20 FEBRUARY 1962
Salon International des Composants Electroniques. Parc des Expositions, Porte de Versailles. Details: S.D.S.A., 23 rue de Lubeck, Paris 16e, France.

MONDAY 19—FRIDAY 23 FEBRUARY 1962
International seminar on *Automatic control in iron and steel industry*. Palais des Congrès, Brussels. Details: Sécrétariat Permanent de l'Institut Belge de Régulation et d'Automatisme, 98 chaussée de Charleroi, Brussels 6, Belgium.

MONDAY 26—WEDNESDAY 28 FEBRUARY 1962
A conference organized by a joint committee of the I.E.E. and the R.Ae.S. on *The importance of electricity in the control of aircraft*. Details: I.E.E.

WEDNESDAY 7 MARCH 1962
Control and operation of pneumatic furnaces by M. J. McInerney and H. Lewis. 7.30 p.m. John Leggett Grammar School, Scunthorpe. (*I.Chem.E.*)

APRIL 1962
'Exposition meeting' on *Self adaptive control systems*. Details and suggestions: R. H. Tizard, Whitterick, Ellesmere Rd, Weybridge, Surrey (*See also Control, July, p.* 122). (*S.I.T.*)

MONDAY 16—WEDNESDAY 18 APRIL 1962
The Second International Flight Test Instrumentation Symposium. College of Aeronautics, Cranfield. Details: M. A. Peary, The College of Aeronautics, Cranfield, Bletchley, Bucks.

WEDNESDAY 25 APRIL—FRIDAY 4 MAY 1962
Conférence Internationale des Arts Chimiques. Paris. Details: Maison de la Chimique, 28 bis rue Saint-Dominique, Paris 7e, France.

MONDAY 30 APRIL—FRIDAY 4 MAY 1962
Second International Compressed Air and Hydraulics Exhibition. Olympia. Details: W. G. H. Chesher, St Richard's Ho., Eversholt St, N.W.1.

WEDNESDAY 2—FRIDAY 11 MAY 1962
Power Generation and Clean Air Equipment Exhibition, and The first British Exhibition of Space Research and Technology. Olympia. Details: British Interplanetary Society, 13 Bessborough Gdns, S.W.1.

TUESDAY 8—FRIDAY 18 MAY 1962
Mechanical Handling Exhibition. Earls Court. Details: H. A. Collman, Dorset Ho., Stamford St, S.E.1.

MONDAY 28 MAY—SATURDAY 2 JUNE 1962
International Instruments, Electronics and Automation Exhibition. Olympia. Details: Industrial Exhibitions Ltd, 9 Argyll St, W.1.

THURSDAY 31 MAY—THURSDAY 7 JUNE 1962
International Television Conference. Institution building, London. (*I.E.E.*).

NOVEMBER 1961 VOL. 4 NO. 41 **CONTROL**

Mission to primitives

IT IS WELL OVER A YEAR since the first congress of the International Federation of Automatic Control ('Ifac'), and now at last the full proceedings have been published.* Four ample volumes record the meeting in Moscow of more than a thousand delegates from 29 countries, and purchasers will have to pay £45† per set. This is a heavy price, but no respectable technical library should grudge to pay it. The recorded proceedings will not help many students to graduate, nor will they provide many immediately useful tips for men on the bench or drawing board. The volumes are not textbooks filled with congealed learning, nor are they manuals for the practical mechanic. Yet they do mark a distinct, historic step in the evolution of a subject and a profession. The latter, unfortunately, is still an embryo struggling for survival, but the academic study is a lusty infant well clear of the womb.

It is fascinating to browse through the symbol-strewn pages of these proceedings, and to contemplate that among the 300 or so papers there may be another such contribution as Nyquist's famous article in the Bell journal, with a practical significance which is all but invisible at the time of publication.

That near-invisibility of *usefulness*, as so many critics have said, was the great shortcoming of the first Ifac congress. It failed to be recognizably very much concerned with practical affairs. Yet this happens so often at conferences dealing with automatic control and automation. The subject is a general one, amenable to analytical study, and it offers unbridled joy to its more mathematical devotees. The subject also has its particularities, of course, but they tend to be made known in the form of descriptions of special applications, with often rather narrow appeal. There seems to be an undiscovered intermediate zone of general practice which engineers could converge upon and use as a common store of experience and knowledge. To an extent, this flaw of the excluded middle is a consequence of the novelty of the subject, and one should not complain too thoughtlessly.

Nevertheless, while to understand all is to forgive all, we are not yet in the happy position of understanding enough, and there are species of neglect which it would be folly to forgive. Too much lack of communication still exists between theoreticians and plant men, between academic researchers and industrial managers. This was well brought out at the recent machine-tool conference in Manchester.* There, when the subject of automatic control came up, the old men failed to see the point and the young men failed to make it.

That is where Ifac and its national constituents would now most usefully apply themselves—to the broad practical interpretation and dissemination of automatic control knowledge. Perhaps in some of the other member-nations people are already working to this end, but at home there is a woeful absence of visible progress. One knows that among those who serve on the committees of B.C.A.C. (the British constituent of Ifac) there are dedicated, sincere, hard-working men who deserve great admiration. But they strive with very little evident effect. The task is manifestly too big for so loosely organized and insubstantial a body. If it is to provide the industrial service that is so urgently needed, B.C.A.C. must have executive power and money.

Part of the problem was ably put by Academician V. A. Trapeznikov in his introductory speech at the Ifac congress (reproduced in the published proceedings). He said: 'Advances in engineering and science are laying a single theoretical foundation for the whole range of engineering subjects involved in communication and control . . . The development of this single theory is vital to automation. No progress of automatic control theory and engineering, however, is possible without commensurate advances in automation hardware . . . How can we possibly reduce the drain of effort and time involved in trials and errors . . . ? Leaving out other considerations, it may be said that much will depend . . . on contacts and the exchange of information between scientists and engineers in various fields and various countries. The closer their co-operation, the smaller the drain of effort on hopeless projects'.

But co-operation demands at least a measure of common understanding. *Will* to co-operate has to be created. There is need for a mission to the primitives who people so much of British industry. They are still starkly unconscious of sin.

* *Automatic and remote control*, edited by J. F. Coales *et al.* (Butterworths).
† £20 to congress delegates.

* Reported by G. M. F. Williams on p. 93. See also A. E. De Barr's discussion of the machine-tool situation on p. 88.

LETTERS to the EDITOR

Becoming a control engineer

SIR: As one originally trained as a mechanical engineer and who has had the advantage of a full-time residential post-graduate course in control engineering I should like to endorse Professor MacLellan's remarks in *Viewpoint* in your August issue on the importance of post-graduate study.

His remarks on finance are mainly concerned with post-graduate work following immediately on graduation. However, there can be considerable value in a graduate wishing to become a control engineer taking a full-time post-graduate course after some years of industrial experience. In this case the financial problem is likely to be even greater unless the graduate concerned is employed by a company sufficiently enlightened to sponsor him. Perhaps this problem is best tackled by convincing employers that post-graduate study for some of their more experienced graduates is worthwhile.

My own opinion is that the opportunity and stimulation provided by full-time post-graduate study to take a fresh look at the problems of industry while relieved of day to day responsibilities is of equal value to the technological content of the course. It is extremely easy in industry to continue doing things in the traditional manner as it involves a minimum of thought.

Tehran, Iran DONALD S. TOWNEND

● *Professor MacLellan writes: 'Full-time post-graduate courses following some years of industrial experience should certainly be more widely accepted as a necessary part of the higher training of technologists. Apart from a failure on the part of senior management to recognise this or a failure on the part of educational establishments to offer the right kind of courses, the main difficulties are twofold.*

'Although payment of the salary of a graduate on leave to attend such a course is normally a small item in the total budget of companies who employ graduates, it is likely to be claimed that the potential applicant is a 'key man'. The organisation cannot spare the man in the short run, however much he might benefit both the firm and himself in the long run.

'The individual, on the other hand, may be unable to afford the financial loss incurred by resignation and subsequent maintenance on a D.S.I.R. advanced course studentship.

'The objects of a national fund such as I suggested in my Viewpoint *might be extended to cover, say, half the cost of maintaining a man at the average salary of his preceding two years' employment. D.S.I.R. might then be prepared to consider providing a grant to cover the other half of this cost.'*—EDITOR.

Laplace transforms

SIR: May I say how whole-heartedly I agree with the substance of the letter from Messrs. Head and Mayo in the July issue of *Control*. There is indeed a vast number of practical problems in circuitry which may be solved without recourse to transform techniques at all. I made this very point implicitly in my original article when I wrote:

> 'There may well be a case for questioning the widespread use of the Laplace transform by engineers on the grounds that in many cases they are using a sledge-hammer to crack a nut, and that by making the method a commonplace they are to a very real extent shrouding its full power'.

On the other hand, I must disagree with Group Captain Wilson when he states that I 'proposed the adoption' of a unit function such as he describes in his letter in the same issue. I did no such thing. I merely quoted three possible interpretations of the value of such a function at $t = 0$ as an illustration of the danger of ambiguity when no convention is used illustrating from which side one is approaching a limit at a discontinuity.

The convention $0+$ merely means that the lower limit of integration is itself the limit of a (say) as $a \to 0$ from above. It is always necessary to be careful in any double-limit process, but there is no real difficulty in deriving the appropriate transform s for the unit impulse when the lower limit is written as $0+$. We only obtain the value of zero for the transform if we fail to take the necessary precautions about the order in which the different limiting processes approach the zero. There is certainly no need to evade the issue by resorting to the two-sided transform.

H. GRAHAM FLEGG
SQUADRON LEADER
M.A., D.C.AE., F.R.MET.S.
R.A.F. Technical College, Henlow

Mass and gravity

SIR: The difficulty over gravitational attraction mentioned by *Uncontrolled* in your September number is quite easily resolved.

Let us imagine two uniform, spherical bodies A and B with centres separated by distance r. Then the gravitational force of attraction is given by $F = k/r^2$, where k is a constant, and if the bodies are increased in size, n_1 times larger for A and n_2 times for B, $F = kn_1n_2/r^2$. This equation expresses all the experimentally determined facts about gravitational force and we see that k has the dimensions $[ML^3T^{-2}]$, that is, identical with (charge)^2 (see *Nature*, *191*, 588, 1961). It is therefore possible to represent the force between masses m_1 and m_2 by $F = Gm_1m_2/r^2 = G'N_1N_2e^2/r^2$, where G is the usual gravitational constant, G' is a dimensionless gravitational 'constant', N_1 and N_2 are the numbers of pairs of charges in the two bodies (a neutron for this purpose counting as one pair of charges) and e is the elementary charge.

It follows that $G = G'N_1N_2e^2/m_1m_2$ which is dimensionally satisfactory. The number of pairs of charges per unit mass, N_1/m_1 or N_2/m_2, varies slightly from one kind of atom to another, so that G' is not quite constant.

A. E. MARTIN
Sir Howard Grubb, Parsons & Co Ltd
Newcastle upon Tyne

VIEWPOINT

W. C. F. Hessenberg, Deputy Director of The British Iron and Steel Research Association, suggests that wider application of automation is retarded by its growing complexity, so we must . . .

BREAK THROUGH TO SIMPLICITY

When I was a boy, most aeroplanes were biplanes, but there were some triplanes, and, in adventure stories about the future, progress to four or more planes was frequently foreshadowed. Yet in the end, the simple monoplane became the standard pattern. Meanwhile, aircraft engines were gathering more and more cylinders with all their associated bits and pieces, to say nothing of such extras as blowers, intercoolers and injection pumps. Then all of a sudden we had the comparative simplicity of the gas turbine.

A longish period of increasing complexity, followed by a break through to a new simplicity, seems to be a common pattern in technological development. Diode, triode, pentode, double diode-triode . . . then just a little blob of metal with two or three wires sticking out of it. 'Perfection', it has been said, 'is finally attained, not when there is no longer anything to add, but when there is no longer anything to take away.'

Automation is at present in a phase of growing complexity and there seems to be no sign of an immediate advance to simplicity. Unfortunately, this is a barrier to its wider application: people readily develop confidence in simple things which they feel they can understand, but they are put off by complexity. In view of the importance of speeding up the application of automation, what can we do to get over this 'complexity barrier'?

First, let us break through to a new simplicity in our use of the word 'automation'. It should mean, quite simply, the act or process of making something automatic. If anyone thinks there is more in it than that, let him find other names for these other things. We shall make better progress with a short definition in words that we regularly use and understand.

Next, we should give more encouragement to the application of the simpler forms of automation. At present, the more elaborate examples get most of the limelight. Naturally, we are all interested to read about the difficult problems that have been successfully tackled by advanced techniques, such as guided missiles, banking, and integrated process systems. Nevertheless, there are still thousands of people whose daily work consists of the most elementary operations, like moving things from place to place, putting them together, counting, comparing, keeping watch, and giving warning, from which they could be released by quite simple automation. It is here that the greatest potential gains to our economy lie.

Would it not be possible for *Control* to give occasional prominence to examples of simple automation successfully carried out with comparatively modest means? Its regular features are already doing valuable work in encouraging the application of automation, but emphasis on simple automation from time to time might particularly encourage companies, who at present feel that automation is a bit above their touch, to have a go themselves, and, having had a go, to tell us all about it in *Control*.

What price automatic control?

On one computer-controlled exhibit at this year's European machine-tool show, the machine itself accounted for about a fifth of the total cost . . .

Machine tools in transition

by **A. E. De BARR,** B.Sc., F.Inst.P.
Director, Machine Tool Industry Research Association

THE DEVELOPMENT OF MACHINE TOOLS MAY BE SAID TO have begun when a tool-holding carriage was added to a lathe. The accuracy with which cylindrical components could be machined thus became very much less dependent upon the skill of the operator, but he still had to provide the hand- or foot-power to turn the spindle, and to control the relative positions of tool and workpiece. The advent of steam power removed the necessity for the operator to turn the spindle, but he had still to control its speed. From the lathe other types of machine tool were developed, but they all depended upon a human operator for control of the speed of any moving parts, for control of the relative positions of tool and workpiece, and for choice of the correct tool and part to be machined. It was not long, however, before some of the controls required were actually built into the machine, and turret lathes, with semi-automatic control of tool and tool-position, were in use by 1856. Since that time there have been many developments, both in machine tools themselves and in the control systems associated with them. The increasing complexity of modern high-production machines such as automatic lathes necessitates a large measure of automatic control: further, the continuous demand for increased accuracy has made it essential for many purposes to replace the human operator by some form of control system. In turn, the requirements of control systems have influenced the development of machine tools themselves, and now, instead of merely trying to add control devices to existing machine tools, we are attempting to design machines and control systems as an integrated whole.

At the Seventh European Machine Tool Exhibition, held in Brussels on 3–12 September, 1961, machines illustrating almost every stage of the transition outlined above were to be seen. From the ten participating countries—Austria, Belgium, Denmark, France, Germany, Great Britain, Italy, Netherlands, Sweden and Switzerland—more than 700 manufacturers of machine tools and associated equipment showed more than 4000 machines, many of them in full operation. The machine tools exhibited ranged from powered hacksaws to computer-controlled three-dimensional milling machines, and provided examples of the application of almost every kind of control mechanism.

Although the word 'control', as applied to machine tools, is coming to mean numerical control of the relative position of workpiece and tool, the many other types of control device used must not be overlooked, and I intend in this article to consider the different types of control application represented in the exhibition.

It must be made clear at the outset that, from the control point of view, there was nothing radically new to be seen. The interest lay largely in the extent to which different manufacturers are making use of control mechanisms of all kinds on both new and old types of machine tool.

Automatic machines

Automatic lathes—of the bar or chucking type—are essentially developments of the turret lathe. They permit a multiplicity of cutting operations to be carried out automatically, and usually include means for automatically removing the finished component and inserting a new blank. Control of the operations is usually by means of limit switches and hydraulic or pneumatic actuating cylinders.

The number and scope of machine tools of this kind shown at the exhibition were large, and many of the tools look very different from the original turret lathe. But the changes in design to incorporate a greater degree of automatic control have not always been for the better. In far too many instances hydraulic or pneumatic operating devices are just hung on to the basic machine, with the inevitable Christmas-tree effect. Untidy appearance may well have no effect on the machines' operation, but customers must, eventually, be attracted to the machine that also 'looks right'. The exhibition showed that there is a great need, even on relatively simple controlled machines of this kind, to integrate the control mechanism and the mechanical design.

Interesting is the extent to which auxiliary automatic equipment is being applied—means for detecting broken tools, feeders of all kinds for feeding component blanks, etc. A logical step is the combination of machine tools and feeding means in the so-called 'transfer machines', of which there were several exhibited. Unfortunately, to use their space economically, exhibitors limited themselves to relatively small machines, but those shown displayed a high degree of ingenuity in the combination of machining, electric, pneumatic or hydraulic controls, and feeding or positioning means.

Nevertheless, all so-called 'automatic' machines require a great deal of initial setting-up, and are therefore useful only for relatively long runs of one component, and attention has therefore been given to ways of increasing the flexibility of these machines. To this end a large number of the machines shown had been equipped with some form of program control. Usually this meant that there was a separate cabinet associated with the machine, incorporating a plug board or, less usually, a tape reader for five- or eight-hole tape, or, rarely, a punched-card reader. The sequence of operations that the machine is required to perform—feed speeds, spindle speeds, etc.—is set up on the plug

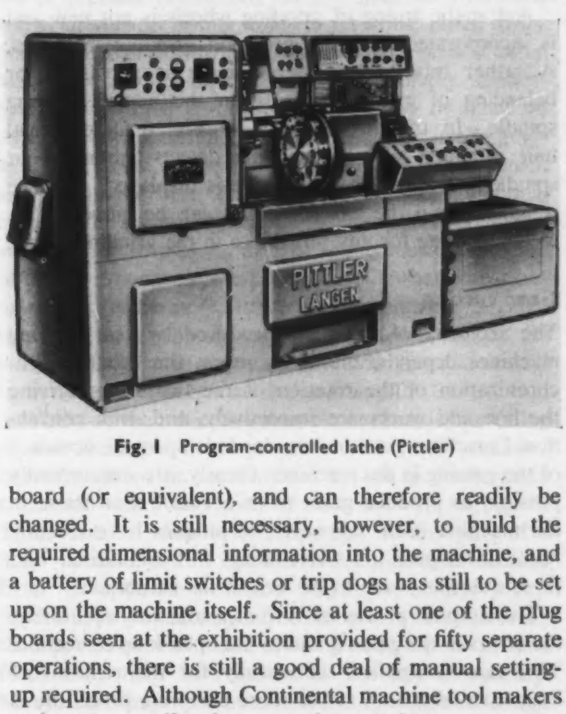


Fig. 1 Program-controlled lathe (Pittler)

board (or equivalent), and can therefore readily be changed. It is still necessary, however, to build the required dimensional information into the machine, and a battery of limit switches or trip dogs has still to be set up on the machine itself. Since at least one of the plug boards seen at the exhibition provided for fifty separate operations, there is still a good deal of manual setting-up required. Although Continental machine tool makers and users are showing great interest in program-controlled tools, interest in this country is not yet very great.

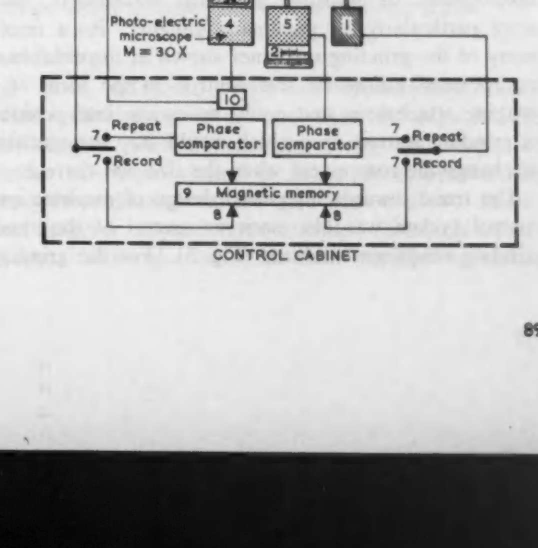
Although the control cabinet is often separate from the machine, there is a growing tendency to integrate the design, often with quite pleasing results (Fig. 1).

On a small number of machines of this type the plug board or punched tape includes dimensional information also, thus very much increasing the flexibility (but also the cost) of the system. Numerical control of co-ordinates is discussed below, but, probably for sound economic reasons, has not yet been extensively employed on automatic lathes or similar machines. One feature of which advantage is now being taken is that numerical control can permit a different type of setting-up procedure to be used. The operator machines the first component in the usual way, the control equipment being used to 'memorize' the operations performed. Having been stored in the machine—a type of magnetic-drum storage is used on a jig borer for this purpose (Fig. 2)—this information can then be used to allow the remaining components to be machined or positioned automatically.

A copying attachment was in use on a lathe as early as 1800, but it is really only with the relatively recent developments in servo-mechanisms that great advances have been made in this field. There was nothing particularly new about any of the copying attachments—for lathes, milling machines, etc.—that were exhibited. Hydraulic or electrohydraulic servo-mechanisms were most apparent, but purely electrical systems were also used, and on one very large machine a milling spindle capable of 40 hp was controlled by an electrical transducer. There is, of course, very little actual setting-up required on a copying machine, but the template or master has to be prepared. Again, numerical control permits this step to be omitted, and one very large copying lathe provided for copying from a template or by numerical control (Fig. 3).

One rather special kind of automatic machine tool was shown, which, although it incorporates numerical control for five independent axes (two on the work table and one for each spindle), is conveniently discussed here beeause the most obvious features of its operation

Fig. 2 Co-ordinate storage system for a jig borer (S.I.P.): 1 Synchros governing micrometer setting, 2. 3 Synchros governing coarse setting of moving member. 4 Photo-electric microscope for fine position-sensing. 5 Servo-motor driving micrometer, 2. 6 Servo-motor driving moving member.



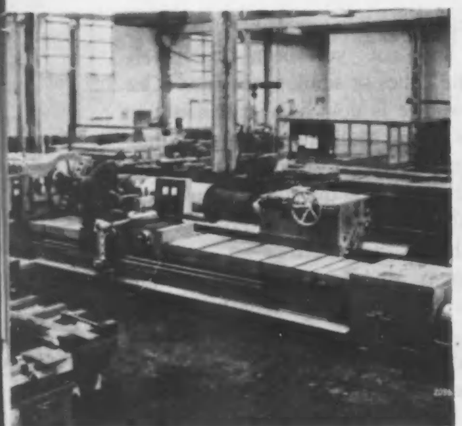


Fig. 3 Numerically controlled profiling lathe (Waldrich Siegen)

Fig. 5 Automatic internal grinding machine (U.V.A.)

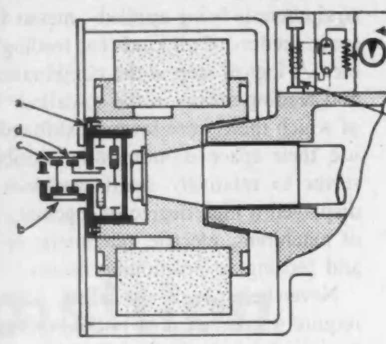


Fig. 6 Balancing device (Hartex): a Mechanical balancing unit b Operating control. c, d Setting rings. e Electronic measuring and indicating unit. f Mechanical vibrator.

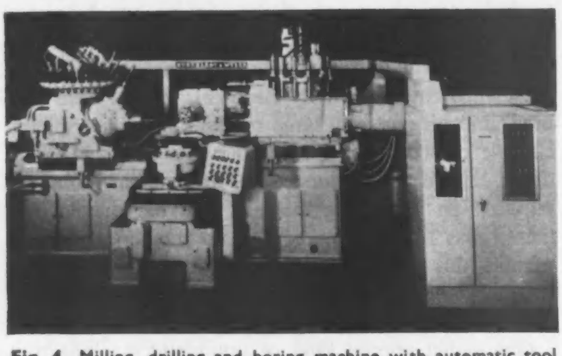


Fig. 4 Milling, drilling and boring machine with automatic tool changing (Burkhardt & Weber)

closely resemble those of conventional automatic machines. It is a combined milling, drilling and boring machine with three separate horizontal spindles 90° apart (Fig. 4). Any one of thirty drilling heads or fourteen boring heads can be selected automatically, tools being changed hydraulically under command from the tape. A wide range of spindle speeds and feed rates can also be chosen in the same way.

Another new development was the use of servo-assisted manual control for at least one large machine.

Grinding machines

Since machined components are ground to finish them to close limits, it is not surprising that grinding machines should be, apparently, the first machines to use feed-back control of actual machined size. Technically, of course, this has been possible for some time—since the development of sensitive electrical transducers, and, more particularly, of pneumatic gauging. As a result, many of the grinding machines shown in the exhibition incorporated automatic size control, in the form of a gauging attachment that could be swung into position as grinding started, and which would stop the machine or change the component when the size was correct.

The trend towards integrated design of machine and control system was also seen in several of the small grinding machines exhibited (Fig. 5). For the grinding of complicated profiles, manual control is facilitated by providing means for projecting a magnified silhouette of workpiece and grinding wheel on to a screen on which the required profile can be displayed. The operator thus controls the in-feed of the grinding wheel according to the relation between the actual and desired profiles as seen.

Automatic truing of grinding wheels is not new and is incorporated in many precision grinding machines. A rather more recent development is provision for balancing of grinding wheels on the actual grinding spindle. In the device shown in Fig. 6 an electrical unit mounted on the machine detects vibrations at spindle speed and the amplitude is displayed. Balance weights within the balancing unit can be moved so as to compensate for any unbalance in the grinding wheel.

Gear cutting

The accuracy of the gears produced by gear-hobbing machines depends, ultimately, upon the accurate synchronization of the rotation of the two shafts driving the hob and workpiece respectively, and, with conventional machines, this in turn depends upon the accuracy of the gearing in the machine. Clearly, it is not normally possible to produce gears more accurate than those in the machine itself. However, techniques have recently been developed for overcoming this limitation, and three examples were to be seen in the exhibition.

The simplest procedure is to measure, very accurately, the errors in the gearing and to use open-loop correction. This can be applied successfully for the removal of long-term errors. A rather more elaborate procedure is to use optical gratings (of the radial type) on each shaft, and with these to produce a signal proportional to any error that exists. Closed-loop control can then be used to correct the error. This system, the efficacy of which depends ultimately upon the accuracy of the gratings, is most effective with long-term errors.

An alternative approach is to use an accelerometer to detect the irregularities of movement, and to let the developed signals generate correcting actions. This

technique is best suited to the corrections of short-term errors, and, for complete correction, must be combined with one of the other systems.

Numerical control

Hitherto, Continental manufacturers of machine tools have not shown much interest in numerical control, i.e. in systems for supplying to the machine in numerical form the information required for adjusting the relative positions of tool and workpiece. This year's exhibition showed a marked change in this attitude, and although the level of manufacturing interest is still far below that currently shown (for example) in the U.S.A., there is evidence that it is increasing rapidly. Some indication of the present position may be gathered from the fact that several Continental manufacturers were exhibiting numerical control equipment that was not yet connected to the machine: a common story was that the controlled machine would be available in twelve to eighteen months; in other instances, prototype machines were on show, and all these exhibits seemed to attract a great deal of attention.

The commonest application of numerical control is for co-ordinate positioning on machines such as horizontal or vertical boring mills, turret drills, radial drills, planing machines, turret lathes, etc. Provision is often made for punched-tape control, but in many applications the required co-ordinates are set up by hand on switches, the machine then positioning itself automatically. Few of the machines exhibited show much sign of having been designed for use with numerical control: the measuring elements are often very obviously added-on to an existing design—sometimes, in the case of optical gratings, in what seems a somewhat precarious manner. Furthermore, the control equipment is often contained in a separate cabinet mounted alongside the machine. Other manufacturers have been more successful in arriving at an integrated design (Fig. 7).

Whilst on the subject of control panels, it is interesting to note the rapid development of elaborate 'pendant' control panels (for conventional as well as numerically controlled machines) such as can be seen in Fig. 7. These can be taken by the operator to any part of a large machine, and he can therefore control the machine from the optimum position. Originally, control panels of this type contained only STOP and START buttons: then provision was made for slow traverse (INCH) and from there they have grown in size and complexity. Many of the larger pendants now incorporate a schematic diagram of the machine, so that the function of the various controls is more clearly evident. The latest development is the incorporation in the pendant of the setting switches and digital display of position as determined by the numerical control system.

For co-ordinate positioning, the path taken by the tool or workpiece to travel from one position to the next is unimportant. The operator sets up the required position and allows the machine to find it. Co-ordinate positioning systems usually work on two axes, but positioning is often sequential, only one driving motor being provided, this being switched in turn to each axis. This is not such a limitation as it might appear, since for many jobs one co-ordinate is common to a number of holes. Zero-shifting facilities are usually provided so that the numerical position system can be made to operate from any desired zero position in the workpiece: alternatively, each hole can be programmed from the previous one, rather than from a common zero.

Perhaps the most interesting features of the numerically-controlled machine tools shown were

1 the very wide diversity of measuring systems in use;
2 the fact that, despite the wide variety of systems already developed and not very extensively applied as yet, many machine tool manufacturers are developing their own numerical control systems; and
3 the fact that the established manufacturers of control equipment for machine tools—E.M.I., A.E.G., Brown-Boveri, etc.—were showing control systems adapted for use with various kinds of measuring system.

No one measuring system seems yet to have established itself as superior to the others, and many systems are in use, although the number is still considerably less than in the U.S.A. The most commonly used (and probably least accurate) system depends upon the accuracy of the leadscrew or rack (sometimes with cam-correction for known errors), position being measured by synchros or digitizers (optical or electromagnetic). In a development of this basic technique, a digital micrometer is used to effect the fine control of position to 0·01mm. Probably the next most popular systems are those based on the well-known Inductosyn or Helixsyn, but optical methods are also used extensively. These include systems using moiré fringes, systems using relatively coarse gratings with means for interpolation, and systems based on the existing scales for optical measurement of position, with suitable graticules and electro-optical scanning heads for interpolation. Thus analogue, digital, and a combination of the two methods may be used for measuring purposes. But the setting-up of co-ordinates and the display of position is almost invariably digital, although one manufacturer has developed an analogue system for fine setting that, in conjunction with digital display of the coarse setting, is very convenient to use. The accuracy claimed for the various systems ranges from 0·001in to 0·0001in. In an attempt to overcome one disadvantage of grating systems—their lack of 'uniqueness' at any position—one instrument-maker has developed coded linear gratings which include both coarse and fine scales.

Contouring

The most advanced type of numerically controlled machine tool is one that is capable of machining a three-dimensional form. Although a number of these systems is under development, no strictly three-dimensional machine was on show. There were, however, at least three so-called 3D machines to be seen: although these can be controlled in three

dimensions, they will control only in two dimensions at any time, and are often referred to as 2½D machines. In actual operation, these machines—usually vertical milling machines—are not very different from a co-ordinate positioning machine with simultaneous positioning on both axes. They require similar measuring elements and feed drives. However, since the path taken by the tool over the workpiece is now all-important, much more elaborate control of the machine is required.

One machine shown, a small vertical milling machine for die-sinking, incorporated its own computer for translating the design data into instructions for the machine. On the other two machines of this type shown, how-

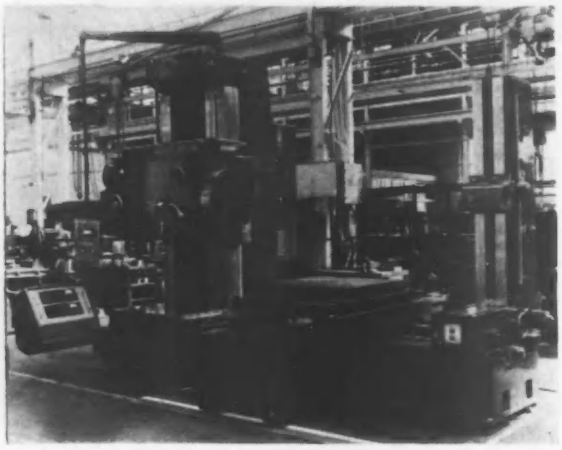


Fig. 7 Numerically controlled horizontal boring machine (Richards)

ever, the information had been put on to magnetic tape by a central computer, thus letting the computer be used more efficiently. Even with the magnetic tape control, however, the cost of this type of equipment is so great that users are obviously still uncertain about its economic potentialities—on one machine shown the actual cost of the machine itself represented only about 20% of the cost of the installation!

The problem, of course, is in the computing, or rather in the combination of computing and the data supplied by the planning engineer. In so far as the required contour can be specified in terms of a series of circular arcs the problem is relatively simple, but even here corrections for cutter radius are a complication. When more complex shapes have to be machined, the problem becomes one of interpolation between the points programmed. The systems of interpolation that can be used vary greatly in their complexity, and the whole problem of programming the computer for machining operations seems far to exceed the other problems.

It is interesting to note that, of the five contouring systems shown in the exhibition, three were by British manufacturers, who are undoubtedly far ahead of their Continental competitors in this specialized field. Of the other two, one was essentially one-dimensional (cam profiling), and one two-dimensional (profile-turning).

One problem with this type of machine is to be sure that the program fed to the machine is correct. Sometimes the control equipment is duplicated; sometimes special checking procedures are used. For use with the numerically-controlled profile-turning lathe shown in Fig. 3, a plotting table was provided so that the profile represented by the input tape could be checked before being fed to the machine.

Miscellaneous

The items discussed above represent the more striking developments in the control of machine tools. Numerical control is the most interesting, but there are also important development along less exciting lines.

Switches, hydraulic valves and cylinders, pneumatic control equipment and electrical equipment, are all important items of control systems. Magnetic amplifiers for motor speed control, for example, or hydraulic motors for table feed drives, are relatively new developments, and there were many examples of these and other similar equipment.

Some attention is also being given to production control equipment. At least one machine was equipped with means for preparing, on punched tape, a history of its own activities—speeds, number of components machined, time stopped etc., although whether this was to meet a real need or merely to be in the swim with some kind of punched tape attached to the machine is not really clear! There was, nevertheless, a more comprehensive type of production control system exhibited on one stand. Indication panels resembling mimic diagrams show the loads of the various machines and the state of completion of orders, and all the data required for accurate invoicing and payroll accounting are registered by counters and graphic recorders.

Other features of 'control' interest were: various kinds of automatic sorting apparatus for sorting machined components according to size, pneumatic and optical measuring equipment (including optical gratings and graticules measuring to 0·001mm), automatic strip- and bar-feeding devices, pneumatically controlled 'hands', etc.

The big question

There are so many difficulties involved in drawing conclusions from the items on view at an exhibition that it is perhaps hardly worth while to try. One is either tempted to speculate on the absence of certain machines known to exist or to be under development, or to assume that the machines shown are fully representative. Furthermore, it is rarely possible to do more than make a guess at a machine's real capabilities by just looking at it.

But, all these difficulties apart, this exhibition did suggest that Continental (and British) machine tool manufacturers are well aware of the potentialities of modern control devices and systems. The technical merits of most of these are not in dispute: the big question is the extent to which they can, in present circumstances, be economically used.

Basic research must be communicated to the machine-tool industry in terms which it understands, and there is need for co-operation based on mutual respect

Machine tools—*design and research*

by G. M. E. WILLIAMS B.Sc., A.M.I.E.E., *Northampton C.A.T.*

THE SECOND INTERNATIONAL MACHINE-TOOL DESIGN AND Research Conference took place from the 25 to 29 September 1961 at Manchester College of Science and Technology.

About 380 people attended, just over half of them from British manufacturers and users of machine tools; a quarter of the attendance came from British higher educational establishments, and an eighth from research organizations outside universities but concerned with machine-tool problems. Despite the intention to make the conference international, and the fact that a tenth of those present came from overseas, this representation was almost entirely from western Europe. A large delegation from Czechoslovakia did not arrive as intended, only one U.S.A. manufacturer was represented by nationals of that country, and there was not even an observer from the U.S.S.R., which is widely considered to be one of the most active countries in this field of enquiry. Nevertheless, when the proceedings are published, world-wide attention will no doubt be given to them, and it is to be hoped that future meetings will be fully supported from abroad.

Forty papers were delivered, but only three were by authors in British firms of machine-tool manufacturers. Nine were by foreign authors, and some of the most interesting were among these. Eleven could be described as precisely or mainly concerned with the application of measurement and automatic control to machine-tool research, design or operation.

Sir Steuart Mitchell opened the conference with a brilliant quantitative comparison of the last 25 years' major advances in aircraft, aero-engines, electronics and industrial chemistry, with the stagnation in machine tools. He pointed out that the weakness derives from lack of effort and not from lack of ability, and thought that not enough use was being made now of the help which could be given by neighbouring branches of technology such as electronics and automatic control.

Professor Johnson (Manchester C.S.T.) took the chair for the first plenary session. He made a significant aside to the effect that the initiative in launching this conference and its predecessor might well have been taken by the professional institutions, but that instead it was the universities which had exerted themselves. Professor Koenigsberger followed with an interesting historical review of machine-tool technology. Ing. J. Vrymer (Research Institute for Machine Tools and Metal Cutting, Prague) was not present, so Professor Koenigsberger read his paper on general considerations in applying numerical control to machine tools. Professor Koenigsberger had earlier visited Ing. Vrymer's Institute, and so was able to supplement the paper to some extent. The argument of the paper was based on an analysis of the most likely shape of the workpieces to be produced in a particular type of machine tool, e.g. shaft-like pieces of substantially rectangular form viewed perpendicular to their axes are the most frequent products of centre lathes. This led to familiar considerations of workpiece and batch size, manner of operation calling for visual and automatic indication of tool position, establishment of program datum points, tool-size compensation, and the accuracy and speed of response of the control system. The slides shown included an illustration of a vertical boring machine (with indexing head and 24kW motor drive) which appears to have been the target for the associated application of all the major forms of automatic control of machine tools—magnetic-tape program for roughing, profile-copying for fine work, wide-range speed control by a Ward Leonard system, and remote position indication. The machine may also be manually stepped through a sequence of operations. One would have liked to ask the author for his views on the significance, for his arguments, of methods of material-forming other than cutting, which latter he appeared to consider exclusively in developing his discussion.

The afternoons usually provided two simultaneous sessions. As a result of real effort made by the very competent organizers to separate the topics of these sessions, it was possible, for once at a conference, to be largely free of gnawing anxieties about the nature of the papers being delivered simultaneously elsewhere.

Promising papers

One of these sessions on the first afternoon presented three papers which by titles sounded most promising: *Output stiffness characteristics of continuously controlled machine tools* by Dr J. K. Royle and A. Cowley, the latter's *Some performance limiting features of machine tool control systems*, and *Design problems involved in*

the development of a linear hydraulic drive employing two short stroke cylinders by R. Bell. The first paper was presented in the author's absence, and suffered in consequence; it was difficult even for the expert to follow it, and there were numbers of points of fact which could not be answered. In particular, the first contribution to the discussion from the floor was by a representative of a British machine-tool manufacturer, who asked bluntly for the significance of the paper to a machine-tool designer. So, instead of the session improving the communication between researcher and designer in this important branch of technology, at least one member of the large audience was repulsed. The paper set out to deal with the difficult problem, posed in a profile-copying control system, of combining the precise position of the tool with stiffness adequate to ensure that the tool cuts the workpiece to the specified size and finish.

Mr Cowley's own paper was concerned with the interrelated problems raised by the friction experienced at rest and over the range of operating speeds of a machine-tool table, and the need for correct damping of the motion of the table. The Coulomb friction/damping non-linear interrelation had been analysed by him using the describing function. Mr Bell's paper was concerned with the novel hydraulic drive, on which earlier work by Dr Royle and others connected with it had been published in *Control* (1959 and 1960). The present paper was confined to one main aspect, the difficult problem of exchanging the drive from one cylinder to another at the end of each driven stroke without disturbing the smoothness of motion of the driven member, usually a machine-tool table. The basic advantage claimed for the drive is that it will cover long travel, far in excess of the length of a stroke of either of the identical cylinders, while keeping the stroke short and so avoiding the non-linearity which otherwise arises from oil compressibility in the cylinders. The exchange of drive described in the paper was effected by an electrical system, and much of the time of presentation was given up to a rather uninteresting description of the practical difficulties of designing clamps to secure (with respect to the bed) the cylinder chosen at any instant to drive the table of the machine tool. There was no satisfactory answer to an enquiry as to why a mechanical method of exchange of drive had not been studied instead of the electrical system. One left this session feeling that the manufacturers and their designers in the machine-tool field were not yet in good intercommunication with the university workers striving to help them.

In a later session of the conference there was a paper from the firm Heid (Vienna) describing an ingenious and admirably simple system of program control for a lathe with turret and profile-copying attachments. This depended on the insertion into the lathe of notched reference bars, with the notches sensed by microswitches, to set the datum and initiate the steps in the program which was set up on a board reminiscent of a plug-board for an analogue computer or punched-card machine. One bar was required per direction of motion, and could be set in position with a simple fixture and dial gauge. No electronic circuits were used, and no problem of staffing with new skills could arise. Some delegates wondered about the worth of such a control system, bearing in mind the vagaries of materials for workpieces and tools.

The Production Engineering Research Association provided two papers of note, one by T. M. Burchall *et al.* on hydrostatic slideways, and another by R. A. Hallan and R. S. Allsop on a strain-gauge dynamometer for boring. Both these papers were extremely well presented, and the Association could do much good by issuing a short pamphlet on the methods it has developed.

B. J. Davies unveiled the Staveley Group's displacement-measuring system, which uses a coarse grating as the reference. This will provide a high order of interpolation within the grating pitch. Further papers on alternative and allied topics came from A. A. Shepherd and D. F. Walker (both of Ferranti), and a well-received contribution from W. H. P. Leslie (N.E.L.).

The closing plenary session included the paper by Dr J. Dyson and R. J. Tillen (A.E.I. Aldermaston) on the Rodolite, an instrument ingeniously based on an optical transmission diffraction grating of concentric, equally spaced, circles, which produces a sequence of central bright spots whose locus is the straight reference which is the purpose of the instrument.

Deployment of manpower

At the close it was announced that the Third Conference would assemble in Birmingham in a year's time. Well over a hundred of those attending were from the research and/or education sphere, and one wonders whether we can afford as a nation to withdraw them from their own work for as long as a week once a year, and whether they will find enough work of quality produced per annum in written papers to make their attendance worth while. The idea of these conferences is an excellent and healthy one, but I believe that, as it develops, two urgent problems must be in the forefront for solution. First, much more attention must be paid to communicating basic research to the industry in terms which is understands and can easily weigh for the purpose of application, and no doubt the reverse flow of information could be improved. Secondly, whilst rivalry between different schools of thought is stimulating, there was evidence at the conference of criticism not as far removed as it should be from back-biting. We have too few resources of men, equipment and finance in this field (and indeed in many others in Britain) to permit ourselves the vicarious pleasures of snarling at the other fellow. Instead there is a need to nurture and develop a high degree of co-operation between those working in this field, based on mutual respect, and of a type we can happily point to in the British field of measurement and automatic control.

Electronic hybrid amplifiers for industrial temperature measurement

by **R. J. REDDING** M.I.E.E., *Constructors John Brown Ltd**

WHILST IT IS NOT EASY TO PROVIDE THE PERFORMANCE of a galvanometer-type amplifier by purely electronic circuitry, the disadvantages of delicate mechanisms for field use, where vibration and inclement surroundings must be expected, is evident. Similarly the use of a 'chopper' and a.c. amplifier system for drift correction introduces troubles when spurious alternating voltages are superimposed on the amplifier input. This article describes d.c. amplifiers specially aimed at overcoming these site hazards.

Since reliability is of paramount importance, the number of active components is kept to a minimum by the use of a novel technique of impedance matching between valve and transistor stages. It is claimed that the unorthodoxy of the designs is justified by the invulnerability in the field.

In the main, two types of temperature-sensing element are encountered: (1) resistance thermometers (usually with a platinum element) for ranges up to about 800degC, and (2) thermocouples for temperature ranges up to about 1700degC. For the former a comparatively simple amplifier suffices. This will be described first. For the latter, much greater sensitivity is necessary and certain hazards become very prominent. In both amplifiers the desired output is a current of 0–15mA into 0–2000Ω, linearly representing the measured temperature, for the operation of indicators, recorders, controllers, data loggers, etc.

Novel circuit technique

An unusual circuit technique (*1*) is shown in Fig. 1. The current through a valve or transistor is derived from an a.c. mains source *via* a bridge rectifier. A current transformer is included in the mains supply circuit, its primary carrying the a.c. equivalent of the direct current I_m. If the secondary of the transformer is connected to a rectifier and a load resistance, the voltage across this resistor will be directly proportional to the current and highly insulated from it. By impedance conversion the circuit gives an apparent gain which is a fixed value determined by the turns ratio. For a direct current I_m of 0–15mA, the voltage drop across the primary is quite small—approximately 7V—for an output of 0–200V across 0·5MΩ with a linearity of one part in a thousand. The transformer, rectifier, and output load are contained in a small sealed unit approximately 1in × 1½in × 2½in which, for convenience, has been termed an

Amplifiers for use with resistance thermometers and thermocouples, employing a combination of valves and transistors, are described in this article. A novel impedance-matching circuit, based on current transformer principles, gives very high gains with a minimum of active components. The amplifiers are intended for the process field, and are designed to minimize the effect of industrial hazards such as low insulation, earth circulating currents, and a.c. pick-up in the connecting leads.

* At the time of writing, the author was with Evershed & Vignoles Ltd

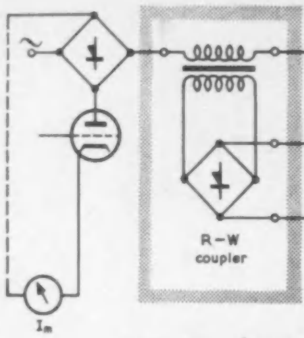


Fig. 1 Use of R.W. coupler—basic circuit

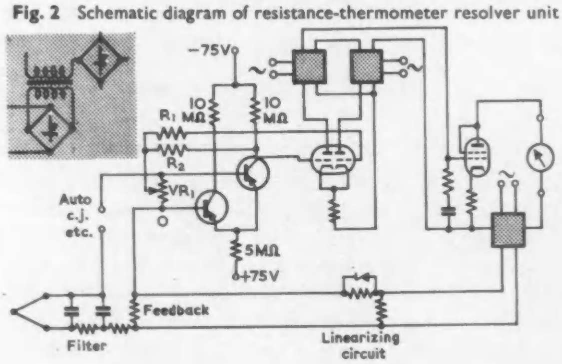
'R.W. coupler'. It was originally developed for feedback integrator circuits, and its value in the amplifiers to be described lies in its ability to couple successive stages without a d.c. through-circuit.

Resistance thermometer resolver

The amplifier for use with resistance thermometers is shown in Fig. 2. The thermometer is a remote arm of a bridge fed from a Zener-stabilized d.c. source. Unbalance of the bridge changes differentially the base currents of the pair of transistors, energized from an a.c. source *via* 'R.W. couplers' and bridge rectifiers. The outputs of the couplers are connected in opposition to a high-slope output valve whose anode-to-cathode circuit is completed *via* the indicating instruments, etc., and a feedback resistor in the thermometer bridge. The system is thus a bridge-balancing method without moving parts, the changes in resistance of the thermometer with temperature being balanced by the voltage drop of the output current across a resistor. The unit has built-in testing and adjusting facilities which permit the unit to be initially set and subsequently checked on site without further equipment, by means of two resistors representing the upper and lower temperature-range points. These are switched into the bridge in place of the thermometer and the zero, and full-scale output is adjusted by RV1 and RV2 if necessary. Since 'three-wire' leads compensation is employed, the resistance of the leads to the thermometer can be any value less than 10Ω (provided the three leads are identical), the actual value being catered for by the test facilities, which can be seen in Fig. 3.

The valve has a mutual conductance in excess of

Fig. 2 Schematic diagram of resistance-thermometer resolver unit



7·5mA/V. The couplers provide 2V for 15μA difference in the collector currents which results from a base current change of less than 1μA. Hence the dependable current gain is 15,000.

The transistors can be regarded as variable resistors and are largely self-compensating for temperature changes. In practice the difference in their temperature coefficients results in a zero shift with temperature of not more than 2mV over 0–45° for unmatched silicon transistors type-OC201. Hence the minimum range of the equipment is 0–250mV, corresponding to 25Ω change, i.e. 50degC with a platinum resistance thermometer (0degC = 130Ω).

The current-feedback bridge-balancing system results in an output which is strictly proportional to the resistance-change of the 'unknown' arm. The resistance-changes of platinum and nickel thermometers with temperature are slightly non-linear according to the range employed. To obtain an output linear with temperature degrees, a non-linear resistor, e.g., a silicon diode, is connected in series or parallel with feedback resistor to

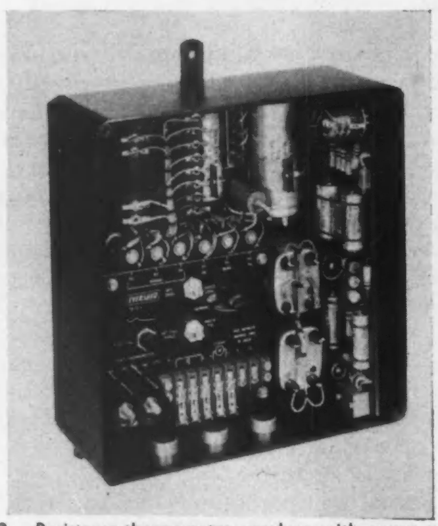


Fig. 3 Resistance-thermometer resolver with cover removed, showing test and adjustment facilities

vary the effective feedback ratio over an appropriate part of the range. Such linearization simplifies the calibration of indicators and recorders' charts and is essential for digitizing and print-out logging.

Thermocouples v. resistance thermometers

As a general rule, resistance thermometers are far superior to thermocouples as temperature-sensing elements. The signal available is much larger, greatly simplifying amplifier design and 'suppressed-range' working, and problems such as cold-junction compensation and connecting leads of special material do not arise. The resistance element is invariably insulated from its protective covering, easing earth leakage problems, yet the time constant can be comparable with that of a thermocouple. The disadvantages are that resistance

thermometers are more complex, less easily repaired, and are not generally available at present for temperatures exceeding 1000°C. (There is also a special case in nuclear reactors where the radiation flux appears to affect the resistance of platinum more than the thermo-electric characteristics of certain couples.) Because thermocouples must be used for above, say, 1000°C (and perhaps for reasons of tradition), there is a tendency in some industries to use thermocouples exclusively, often at unnecessary expense and loss of performance. However, the need arises for an amplifier which will provide a signal for instrumentation purposes, the minimum input being 10mV d.c., corresponding to approximately 1000°C with platinum/platinum 10% rhodium thermocouples. For other couples the signal is considerably greater.

Special requirements in the field

A thermocouple will be electrically in contact with its protective sheath, either intentionally for fast response, or because available insulators tend to conduct at high temperatures. The couple is therefore either connected to earth, or, owing to spurious voltages, is at a potential above earth, in a low-impedance circuit. If a second 'earth' occurs in the circuit at the amplifier or at the receiving instruments, circulating currents either a.c. or d.c. may occur which could give faulty operation. On industrial sites voltages in excess of a thermocouple's e.m.f. can be expected between 'earths' at two separate points, owing to power supply unbalance, fault currents and cathodic protection, or electrolytic action. Various amplifiers have been specially evolved (e.g. *2*) to mitigate these circumstances. These may isolate the amplifier output from its input and/or insulate the amplifier from earth and connect it by a guard wire to the thermocouple. Whilst this can virtually eliminate difficulties of circulating currents *via* earth paths, there remains the problem of spurious alternating voltages induced in series with the signal, e.g., in the thermocouple circuit. These may be considerable in certain applications such as electric furnaces and rotating machinery where the a.c. flux level is high, or where numbers of couples are connected in series for averaging or differential measurements.

To achieve a range of 10mV the amplifier drift from all causes, referred to the input, must be less than 100μV, and conventionally one would employ a chopper and a.c. amplifier for this purpose. However, a small value of a.c. component, say, a few mV, would cause saturation of the a.c. amplifier. This may be improved by the use of filters, but practical limitations such as pick-up in the filter itself and the response to changing amounts of ripple are soon felt. Chopping at a high frequency with semiconductor devices does not seeem to be a solution. A zero-monitor system can sometimes be used with advantage, e.g., in high-speed scanning and logging, where an 'off' period is available for zero checking. However, for continuous control, the step changes resulting from zero correction would be intolerable, since they would prohibit the use of derivative action, which is so important in temperature control.

For these reasons a 'straight' d.c. amplifier with an extremely high a.c. rejection factor was tried. This meant sacrificing some of the anti-drift performance in favour of the ability to work in the presence of large spurious potentials.

The specification for the instrument described below is:

Minimum range with feedback—0–10mV.
Output—0–15mA d.c. into 0–2000Ω linear with temperature.

The amplifier is affected by less than 1% by any of the following conditions:

1. **Ambient temperature change 0–40°C.**
2. **250V a.c. or d.c. between input and earth, output and earth and input and output.**
3. **100mV a.c. 50 c/s or higher, in series wih thermocouple.**

The thermocouple amplifier

The amplifier (*3*) employs two transistors in a balanced-input 'long-tailed pair' stage, coupled to a double-triode valve, working more or less as an electrometer, which drives a final output valve. The input and outputs of the amplifier are isolated by the use of the current transformer principle already described. A simplified circuit is shown in Fig. 4.

The transistors are used at high voltage in the starvation mode, with collector resistors of 10MΩ which result in a voltage gain of approximately 1000 since the collector load is not shunted significantly by the following

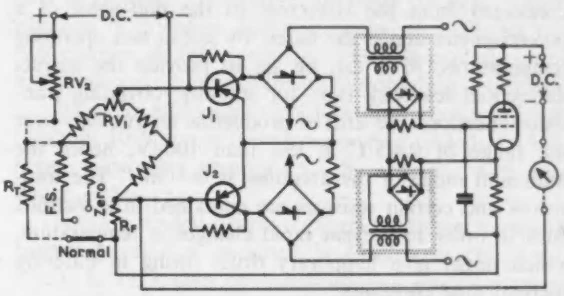


Fig. 4 Simplified circuit for thermocouple d.c. amplifier

valve stage. The emitters have a common 5MΩ resistor, and hence the common-mode rejection factor of the circuit is also approximately 1000. The input impedance of the circuit is approximately 300kΩ, which allows the use of an *RC* filter partially to reject any a.c. component which, together with the rejection of the transistor circuit, renders the system insensitive to 100mV a.c. The electrometer-style connexion of the double triode also assists, since there is no grid leak or rectification at the grids. The transistor circuit is not connected to the valve cathodes; the double grid connexion ensures that the net grid current of the two halves is zero. The valve anode-to-cathode circuits are completed by rectifiers and current transformers, as in Fig. 1, the two d.c. outputs being connected in opposition to the high-slope output valve. This provides isolation in the forward direction, and gain with economy.

The feedback circuit must also be electrically isolated, and again the circuit in Fig. 1 is employed for the output valve. The large isolated direct voltage so provided facilitates linearizing for the thermocouple characteristic by means of a Zener diode (*4*) after which the required feedback is obtained in a divider network. Automatic cold-junction compensation, zero-suppression voltage and check points, where required, are derived from networks fed from a stabilized d.c. source. These follow conventional practice, and only the point of entry is shown in Fig. 4.

The input required for an output change of 0–15mA is $<0{\cdot}03\mu A$ or $50\mu V$ at the transistor bases. This provides a grid swing of 50mV between the two halves of the double triode, and hence swamps the internal drifts of the valve (type 6158). Valve plus transformers have a voltage gain of 100, giving adequate drive for the output valve. The overall current gain is not less than 500,000.

The limitation of the amplifier lies in the drift of the input stage with temperature. The use of starvation circuitry (collector current $1\mu A$) obviates self-heating errors, and maintains the transistors in a virtually quiescent state, which appears highly desirable for drift-free operation. Further, all variations in the silicon transistors are insignificant in comparison with the available voltages except the I_{CO} and V_{BE}. It is possible to use feedback to compensate for the changes in these with temperature, since the circuit has a voltage gain of approximately 1000. Two resistors R1 and R2 are connected from the collectors to the mid-point of a potentiometer across the bases. By test at two operating temperatures, RV1 can be set to provide the correct differential feedback ratio for stability, obviating transistor selection. The drift of production instruments over the range of 0–45°C is less than $100\mu V$, hence the minimum range of the amplifier is 0–10mV. The transistors and certain resistors are contained in a thermos flask in order to prevent rapid changes in temperature, which might give temporary drifts owing to differing thermal time constants.

The current transformers and the mains supply transformers have double screening, following conventional practice, to render the amplifier impervious to a.c. capacitance effects. The various amplifier stages are also screened, and since the amplifier will operate with voltages of a lethal order between sections, neon lamps are fitted to indicate whether the equipment is safe for servicing.

Discussion of the amplifiers

The novel current transformer technique considerably reduces the number of active components, such as valves and transistors, required for a particular gain; further, the duty on them is less onerous, since they are virtually employed as variable resistors. Using conventional techniques the equivalent performance of the resistance thermometer amplifier would require at least three valves or five transistors, and existing designs for thermocouple applications have approximately eleven transistors. The current transformer system is particularly advantageous when coupling transistor circuits to a later valve stage, by reason of the impedance match and isolation it achieves.

A preference is often expressed for complete transistorizing of equipment because of the apparently longer life of transistors. However, the life of a component in practice depends on the deterioration of the characteristics pertinent to the application, and the stresses imposed on it by faults and abuse during its life. Thus the useful life of a valve as a variable resistor in a d.c. circuit may be far greater than the usually quoted figure, which is based on high-frequency operation where the grid current and inter-electrode capacitances are the limiting factors. Similarly, although a transistor is mechanically robust, a small electrical overload lasting for microseconds can destroy it, and the energy stored on a capacitor after the supply is removed may be sufficient to destroy a transistor during servicing. Thus use of a transistor in the output stage of an industrial amplifier makes it essential to protect against the effects of an inductive load, insulation testing, and spurious induced voltages. This requires the addition of fast-acting diodes. On the other hand, a valve output stage can withstand considerable electrical misuse and overload without deterioration. The use of transistors in the early stages where they are easily protected, and a valve for the output stage, can therefore be justified on the grounds of invulnerability alone.

The amplifiers are special-purpose devices for industrial temperature measurement. Whilst in principle they could be used for general purposes, certain limitations are implicit. For example, the frequency response is limited to approximately one-tenth of the mains power frequency by the time constant of the rectifier circuits. Whilst this is adequate for temperature measurements with a 50 c/s supply, it means that the circuitry is not applicable to, say, high-speed analogue computing, unless a high-frequency power supply is employed.

The amplifiers have no dead zone or threshold, and are approximately linear over the working range. Hence the feedback ratio can be assessed from drift considerations, i.e., the minimum working range is a hundred times the drift, referred to the input, for the worst likely conditions encountered. The figures quoted in this article are based on the minimum of the transistor characteristics spread and the end-of-life mutual conductance of the valve. The drift is virtually due to temperature changes, and since provision is made for test and easy adjustment when installed on site, the ultimate performance depends on the suitable choice of a mounting position and lies largely in the hands of the user.

Acknowledgements

The author thanks the directors of Messrs Evershed & Vignoles Ltd for permission to describe equipment covered by the Company's Patent Applications, and acknowledges the work of his colleagues, P. O. Fuller and S. Warder, in the evolution of the amplifiers.

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The exhibition at Olympia last month showed how important computers have become in the nation's life, but there is no doubt that the country is lagging behind in their utilization

Trends in computers

by **R. J. A. PAUL** B.Sc.(Eng.), A.M.I.E.E., A.M.I.Mech.E., *College of Aeronautics, Cranfield*

ON FIRST ENTERING THE ELECTRONIC COMPUTER Exhibition at Olympia last month I learned from the press hand-out that more than 24 computers were on show, the majority of which had been developed and put into production since the first exhibition in 1958. The estimated value of these machines, together with ancillary equipment on show, was stated to be about £4m. They certainly formed an impressive array, and visitors who also attended the first exhibition must have been struck with the significant reduction in size of the so-called second-generation computers, achieved by the use of ferrite cores and transistor logic. In line with this development there has been considerable improvement in the capabilities and operating speed of input and output equipment.

However, before delving too deeply into detailed technical matters, one might ask what are the significant trends in application since 1958. A few years ago, in this country, a large proportion of the available computers was devoted mainly to scientific applications. During the intervening period, the electronic computer has gradually become accepted more generally in the business and commercial world as a means of performing routine calculations and processing information in a completely integrated system. But Lord Brabazon, who opened the exhibition, thought that British businessmen were still too cautious about computers. He said that we have fallen behind America and the Continent, not in making the computers but in selling them, or, to put it more truly, in applying them. On the Continent there are about 1000 computers installed and working, whilst here in Britain there are only about 350. He believed that the present trouble with the computer is that is has been oversold. The phrase 'electronic brain' had been blamed on the press, but he thought it had originally been coined by the industry itself, though not necessarily in this country. This had been a disastrous step, and he urged computer people to pay more attention to selling computers by finding out the customers' problems and then showing how the computer would help.

It would appear, however, that the businessman is beginning to have a more realistic appreciation of the computer's capabilities as well as its limitations. This is reflected to some extent in computer sales during the last few years, as deliveries of British computers (home and abroad) have risen from about £5·3m in 1958 to about £8·2m in 1960. Sir Edward Boyle, who opened the Electronic Data Processing Symposium held in conjunction with the exhibition, said that direct export of electronic computers in 1960 was well over £2m, and although they fell back in the first quarter of 1961 this was probably not significant. He felt that the export potential would be considerable, and that membership of the Common Market would provide greater opportunity for sales.

Still on the question of sales, it is interesting to note that, as reported in *Electronics Weekly* (16 Aug., 1961), Ministry of Aviation figures indicated that, during the first quarter of 1961, sales of electronic capital equipment reached a total of £16·9m, out of which computers accounted for just under £3m, including an export figure of about £0·25m. In the corresponding period of 1960, home sales were about £1·5m but exports were just under £0·5m.

These are modest figures compared with the American market position as reported in *Electronics* (28 April, 1961). In 1953, sales of stored-program general-purpose digital computers were about $10m, and this rose to $100m in 1956. Last year, sales of general-purpose computers were in excess of $500m, whilst the computer industry as a whole grossed over a billion dollars. The report also states that there are about 4000 valve computers installed, and about 700 solid-state computers.

These figures indicate that the electronic computer is making a significant impact on our industrial and commercial life, although there is no doubt that we, in this country, are lagging behind in utilization.

Process control applications

The application of computers to on-line and off-line control of industrial processes is another significant trend, and one which offers interesting and exciting problems to the control engineer. It is interesting, therefore, to hear the views expressed by a few of the manufacturers' representatives.

The general tendency in this country at the moment

seems to be mainly to use computers to monitor the behaviour of existing plant as a means of getting a better understanding of the particular processes involved. Certain on-line decisions are computer-controlled, but the general view is that much more information about each particular plant is needed before completely integrated computer-controlled systems become a realistic and economic venture.

Dr Aylett (Ferranti) said that the market was slow for on-line process computers although, as announced in the press, Ferranti had two orders for Argus. He predicted that, in the next four or five years, large steam plants in this country would be computer-controlled both as regards start-up and running. He felt that the chemical industry would be somewhat slower in adopting computers in this way. The present problems in his opinion were down-to-earth applications of operational research, and there was not enough experience yet to consider sophisticated methods of control.

Mr Huxtable (English Electric) also confirmed the view that data logging on plants must precede real on-line control. He also thought that experience with existing power stations would allow new power stations

Fig. 1 Panellit 609 system in an American chemical plant. It monitors the process continuously, gives alarms when parameters go outside preset limits, logs all parameters at preset intervals or on demand, and computes stage-efficiencies on-line

to be designed with computer control from the start, as an essential part, and this might result in significant developments.

One very important factor under consideration by people concerned with process control is the reliability of the computer and its ancillary equipment. Dr M. V. Wilkes made some interesting suggestions on this very important topic in last month's issue of *Control*.* It seems that considerable effort is being devoted to the consideration of fail-safe systems and obtaining statistical evidence of component reliability.

With all the major computer manufacturers actively engaged on the process control application, we can look forward to considerable development in this field.

Current computer techniques

Dealing now with the general design aspects of computers, what are the current trends?

A significant feature of today's machines is the use of ferrite-core storage and transistor logic elements, which has resulted in a considerable reduction in access time and a figure less than 1μs is now possible. For

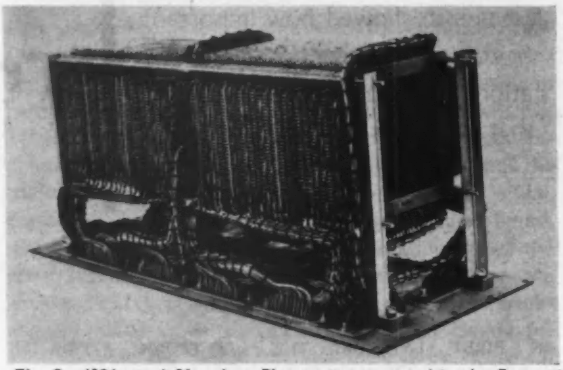

Fig. 2 4096-word fifty-plane Plessey store as used in the Ferranti Atlas computer. Cycle time less than 2μs

example, the core store of Atlas has a cycle time of 2·0μs. In many of the larger computers, this quick-access store is backed up by magnetic drums and magnetic-tape equipment. As already stated, the use of transistors has resulted in much smaller packages. But peripheral equipment is still based mainly on electromechanical techniques, and, in large installations, the need for many of these units means that the space required for the complete system is a fair proportion of that required for the older valve system.

Input and output equipment is the weakest link of the computer system, both as regards operating speed and reliability.

However, improvements continue to be made, and a typical example is the Decca type-4000 magnetic-tape unit, incorporating a pneumatic device for the tape. Standard data rates are 45,000, 90,000 and 180,000 char/s. Another interesting newcomer to this country is the N.C.R. punched-card reader, type-C-380, capable of reading and checking 2000 eighty-column cards per minute. The cards are read photo-electrically, and dual reading stations allow comparative checking without loss of reading time.

Visitors to the exhibition had the opportunity to inspect the first production model of the Rank-Xeronic output printer, which is the development of the prototype demonstrated at the 1958 exhibition. This printer is capable of printing information from the computer on to plain paper at 4700 char/s or 2880 lines/min. The signals from the computer are written by an electronic beam on a c.r.t. screen, and the image is copied xerographically on to a continuously moving roll of paper. Random-access memories are an important facility of present-day data-processing machines, and typical examples include the I.B.M. magnetic-disk Ramac system; the N.C.R. 315 Cram system, employing magnetic cards for both sequential and random access; and the Facit Carousel magnetic-tape random-access memory shown by A.C.E.

Character recognition, particularly in commercial

* *Design of practical self-repairing computer systems*, p. 86—EDITOR

applications, is becoming a significant factor, and automatic reading machines already used in the U.S.A. are now being introduced in this country. Present-day machines are based on magnetic or optical character readings. An example of the magnetic-ink reader is the I.B.M. 1412, which can read and sort up to 950 documents a minute and provide direct input to an I.B.M. 1401 or 1410. I.B.M. also market an optical character reader-meter, type-1418, which can read 480 char/s printed with ordinary ink. A second optical station may be added to the 1418, so that two lines may be read in one pass through the machine with a combined input speed to a computer of 960 char/s.

Clowes and Parks (N.P.L.) presented to the Symposium a paper on character recognition, outlining some of the research work carried out at N.P.L. They analysed existing techniques including the Farrington optical screener and the Solartron model for Era. Magnetic-ink cheque sorters were also reviewed. The authors showed that extensions of existing systems will involve radical improvements in technique and indicated a possible new approach. *They concluded that the long-term prospect in character recognition will lie with the successful development of* optical *readers.*

Programming

Programming is of course the very heart of any computer system and the steady advances in this respect are leading to wider applications of computers. The increased use of 'automatic programming' or 'automatic coding' has allowed the casual user to program the machine itself after a time relatively short compared with that required for a knowledge of machine code.

The introduction of international language codes is a further interesting development. In the scientific field the I.B.M.-Fortran code has already gained a prominent position. In this country Autocode devised by R. A. Brooker (Manchester University) is still in common use. However, in 1958 the requirement for more powerful facilities than those contained in the two codes was considered necessary for a truly international standard language. The discussions amongst programmers of different countries have resulted in Algol 60, formulated last year for scientific applications. It is probable that up-dating will be necessary in future years. Several computers, in addition to their individual forms of autocoding, have already been programmed to accept Algol 60, but experience in its use is not very extensive. In the business field a similar project started in 1959 has resulted in the international language Cobol 61, and yearly up-dating is again anticipated. Several modern computers have again been programmed for Cobol. The next question arises—can these two languages be amalgamated into one standard language for all purposes? Dr Gill (Ferranti Ltd) in a lecture at the Symposium discussed this aspect at some length, pointing out the differing requirements of scientific and business applications. He suggested that, in view of the difficulties involved in achieving full and lasting standardization, a more practical aim might be the establishment of enough common conventions among programmers to make programs readily understood by others. Dr Gill stated that already some £10m had probably been spent in this country on programming, and at least $2000m in the U.S.A.

The use of parallel programming has resulted in the time-sharing facilities, particularly in the larger fast machines such as Atlas. This feature overcomes to some extent the limiting speed of peripheral equipment as several units may be operated in parallel to speed up the processing of data. Alternatively it permits more economic use of the machine for small problems, in that several independent problems may be solved at the same time. Perhaps this feature may provide the small businessman with a more economic computing service.

Data transmission

The introduction of the more powerful computer installations has stimulated interest in compatible data communication between the central computer and data stations. Evidence of this interest was demonstrated at the G.P.O. stand, where examples of telephone and telegraph links were shown. A prototype error-detection equipment for telegraph lines was also demonstrated. The G.P.O., with £1000m worth of equipment available, is obviously anticipating greater use of these facilities for computer applications. The principal A.T.E. exhibit was a high-speed punched-tape input and output data-transmission system for operation over normally available telephone circuits. I.B.M. are active in this field, and a typical example demonstrated was the I.B.M. 1001 data transmission system, comprising one or more links to a central receiving station by dial-telephone lines.

Analogue and hybrid equipment

In such an exhibition the analogue machines can easily be overlooked. Although none of the digital people with whom I spoke could see any great future for analogue

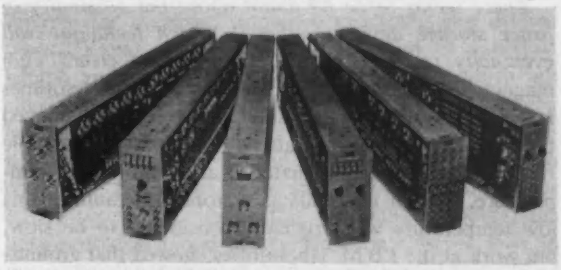

Fig. 3 This digital simulator is a larger and better version of the Armstrong Whitworth Airbric

devices, in view of the versatility and capabilities of the modern digital machine, *I feel that engineers and scientists will still find a great need for analogue computers in the investigation of new and complex systems. The use of adaptive computers in control applications should surely not be overlooked.*

The major manufacturers were represented. E.A.L. demonstrated the 231R with high-speed repetition

operation. Speaking of future developments, Dr Murphy (E.A.L.) thought that the trend would be to incorporate more digital logic elements in an integrated hybrid system to give better memory and other decision and mathematical facilities. The Short educational computer which was on show should find a market in educational institutions. Solartron exhibited their S.C.30, S.C.D.24 and S.C.D.10/20 computers, the latter intended also for the educational market or r. and d. activities.

Verdan, demonstrated on the Elliott stand, was one of the few examples of incremental computers. A.W.A. also showed some interesting d.d.a. computers on behalf of A. V. Roe. These include Airbric, designed for airborne use, and a digital simulator which is a larger and improved version of the earlier Avric computer. Avric has a clock rate of 50kc/s and comprises twenty integrators and eight summers. The digital simulator comprises 120 units and includes decision and switch units. This simulator is being built for the Ministry of Aviation by A. V. Roe at a cost of about £50,000.

Future thinking

Most manufacturers seem to be investigating the possibilities of thin-film storage. Mr C. Postle of I.C.I. said that work on this, as well as character recognition, was being done at Stevenage. Mr Newman (English Electric) said that in addition to basic development of faster storage devices, work was also proceeding on circuit logic elements. He suggested that faster punched-tape speeds might be obtained by using a metal film on a plastic base, with the hole in the form of a puncture obtained by evaporating the metal film locally with an applied voltage. C. H. Devonald (Ferranti) said that there would be a need for faster logic operations to keep pace with faster memory devices. J. Foster (A.E.I.) thought that the next significant break-through would be a self-organizing computer fully auto-coded by hardware.

There seems to be no doubt about the possibility of faster storage devices, although which technique will eventually prove to be the winner is not clear. Thin magnetic-film memory is expected to be about ten times faster than core storage, and it has been announced that the Univac 1107 is already using it. A possible rival as a fast store is material at liquid-helium temperature. Use of materials as a storage medium at this low temperature was originally considered to be slow, but work at the I.B.M. laboratories showed that ground-plane techniques could considerably improve speed. An advantage of these 'cryogenic' techniques is that it is possible to produce associative stores, in which each stored item has an identification symbol, and access to a particular item could be obtained directly by specifying this symbol rather than by the present indirect way of referring to the address at which the item is stored. On the field of cryogenics, Dr Wilkes (*New Scientist*, 28 Sept., 1961) foresees the possibility of a complete computer operating in liquid helium. He also discusses the use of the microwave parametron or parametric oscillator and the tunnel diode as fast switching devices. However, because they are both two-terminal devices, design difficulties occur in maintaining the direction of information flow.

It has been suggested by K. L. Smith (I.B.M.) that combination of transistors and tunnel diodes might prove to be the answer. He also suggests that the solid-state space-charge-limited diode or dielectric diode is another promising possibility, and sees many applications of the equivalent triode device. In his article (*Electronics Weekly*, 17 May, 1961), Smith states however that phase-modulated, sub-harmonic parametric oscillators could be the basis of all computers operating in the microwave region.

An interesting exhibit on the Plessey stand was a tunnel-diode memory with an access time of 25mμs. As operating speeds are increased, the transmission time-delay between units owing to the finite speed of light, becomes significant. The required reduction in physical size focuses attention on micro-miniaturization technique, and these were a feature of the Mullard stand. Mullard's are currently engaged on a method of mass-producing reliable micro-circuits with component packing densities of 300–400/in^3.

On the question of input and output devices, there do not appear to be any startling developments around the corner, but further improvements in existing techniques may be expected.

Development of programming techniques seems to offer exciting possibilities. Dr Gill states that work is already under way on systems that will cause the computer to act as a kind of automatic factory, rather than a tool under the control of a human operator. Dr Wilkes, however, is disappointed that all programs so far constructed for making a machine adapt itself to its environment and acquire experience appear to lack profundity. He adds that it is possible that we lack some fundamental idea which would enable us to make machines play a more active and creative role. Dr Gill still believes that the idea of a thinking machine is not dead, but that we must expect a gradual approach rather than a sudden break-through. He speculates that if the i.q. of computers could be raised to 100 it will certainly not stop here, and presumably computers would then become better than humans at designing and programming computers. *However technical and programming techniques develop, the next decade is likely to be an exciting period both for the designer and user.*

With the accent of papers on application at the Symposium, one can only hope that this country will become more computer-conscious. As Dr Gill said at his lecture: 'Ten years ago this country led the world in computers'. He then went on to say that we had lost our hold because of our failure to appreciate the true magnitude of computer technology.

Perhaps in the next ten years we can fight our way back.

PART 2

International development in this fascinating field of application continues, often on the basis of British pioneering work

Progress in automatic language translation

by **ANDREW D. BOOTH** D.Sc., *University of London*

Logic and structure

The next of the papers from M.I.T. was that by Elinor Charney on 'The Semantic Interpretation of Linguistic Entities that Function Structurally'. This somewhat ponderous title conceals a paper which is effectively about symbolic logic and its application to the analysis of linguistic terms of the conventional sort, such as *either, neither,* and so on. It may be argued that such abstract investigations will not soon lead to practical procedures in translation, but this would be a very false assumption, since mathematical logic is in fact a self-consistent language, to which it is hoped, in the future, natural languages may be reduced.

Edward Klima, also from M.I.T., spoke on structure at the lexical level, and its implications for transfer grammar. His paper was, in effect, a discussion of the differences between such words as *learn* and *know,* in phrases like 'learn a word' and 'know a word', and contained a conscientious attempt to classify such words for machine translation. A most valuable activity, since it is by such classifications that ambiguities and other difficulties will eventually be resolved.

The final contribution from M.I.T. was that by G. H. Matthews, on analysis of synthesis of sentences of natural languages, which was, in fact, a rival version of the predictive analysis technique.

The sister institution to M.I.T. in Boston is Harvard. This University, too, was well represented at the Conference. G. Salton and R. W. Thorpe described an approach to the segmentation problem in speech analysis and m.t. It is not generally realized that one of the great difficulties in the automatic analysis of speech by machine is the apparently trivial problem of deciding where one word ends and the next begins. The same sort of thing applies in the analysis of written text by machine, and Salton and Thorpe considered the use of grammatical indicators and a form of the ubiquitous predictive analysis.

Russian again

William Foust and Julia Walkling, also from Harvard, described a preliminary structural transfer system which was, in effect, a set of transformations which map Russian constructions onto English constructions. Since the discussion was only preliminary, the constructions were described only in very general terms. But sufficient was said to show that the method might with development prove of great utility.

Irina Lynch read a distinctly earthy paper on the Russian ся verbs, impersonally used verbs, and subject-object ambiguities. She provided something which was rare among the papers at the Conference, namely a flow chart, which showed in detail the decisions which must be taken in order to attain an accurate analysis of the Russian text.

Four stages for Japanese

The last of the Harvard contributions, and in many ways the most interesting, was that of Susumu Kuno, who described a preliminary approach to Japanese-English automatic translation. He suggested that four stages were necessary: automatic input editing, automatic segmentation with morphological analysis, syntactical analysis, and transformation with output editing, including semantic transfer.

We have here space to deal only with the first problem—the problem of pre-editing the input text to a form suitable for machine. Japanese characters are of two types: Kanas, which are the equivalent of Japanese letters, and are 71 in number; and Kanjis, which are effectively ideographs and of which there are eighteen hundred and fifty. Kuno's procedure is to code the Kanas into two-letter Roman alphabetical groups and to code the Kanjis using a straightforward binary or I.B.M.-type code. After this preliminary coding, the next problem is one of segmentation, just as it is in the automatic analysis of spoken dialogue. The problem arises because Japanese writing contains no spacing. The method which Kuno proposes is to match dictionary stems and find the longest of these which start the lines of the Japanese text. These stems having been deleted, possible endings are hunted, and processed, and in this way the complete character is isolated and removed from the text. This having been done, the next character is considered, and so on.

In effect Kuno's method is an extension of that pro-

posed originally by Booth and Richens for the analysis of German compounds, and presents few new features. It is, however, most interesting to see that these techniques can be applied to a language like Japanese, which is apparently far removed in structure from that of the European languages.

The Japanese themselves are not inactive in the field of machine translation, and one paper was presented by a Japanese worker, I. Sakai. This dealt with syntax in universal translation, and described proposed experiments in translation, using the Japanese parametron computer, which has among its components cores, drums, and three magnetic-tape units. It is too early to say what results may be expected from these experiments, but it will be interesting to see the progress which the Japanese make.

Mechanized syntax

The Berkeley branch of the University of California is well known for the productions of Sydney Lamb. On the occasion of this conference he read a paper on the mechanization of syntactic analysis. This described a simple program which listed the different words in a 5000-word text, selected from the writings of Winston Churchill, counted the occurrences of words, and then worked out so called 'left neighbour' and 'right neighbour' counts. That is, the number of times that the given word in the text occurs, divided by the number of times that some other word occurs to the left or right of it. A number of examples of such counts are given and some indications are produced which show, firstly the essential difficulty of doing language statistics on any words apart from nearest neighbours, and secondly of the way in which even this limited information can be of great help for machine translation.

Chemical terminology

J. H. Wahlgren, also from Berkeley, discussed the linguistic analysis of Russian chemical terminology. The paper was an interesting and earthy one, which attempted to describe the way in which Russian chemical phraseology works. The description, quite apart from its use in machine translation, should be of great value to anyone who is working in the translation of Russian chemistry.

Dostert's group, from Georgetown University, submitted several papers, and, among these, one by Lawrence Summers discussed the machine translation of Russian organic chemical names. The subject matter was similar to that of Wahlgren's paper just mentioned, but, in the case of Summer's analysis, the argument proceeded by an analysis and re-synthesis of the component fragments of Russian names. He pointed out that the number of possible organic compounds is effectively infinite, so English equivalents of Russian words cannot be stored as a whole. The paper gives a table of a hundred fragmentary equivalents, and a set of rules for converting Russian to English from these. The basic technique is again the old stem-ending decomposition one suggested by Booth and Richens for German compounds.

Obscurity and clarity

The other contribution from Georgetown was that by Michael Zarechnak, who suggested that a fourth level of linguistic analysis was needed to improve the Georgetown programs for Russian–English. At the present time these have three levels of analysis—morphological, syntagmatic and syntactic. The new analysis, which, frankly, I found not entirely comprehensible, was apparently shown to be necessary by the results of practical experiments. Anything indicated by experiment must necessarily be taken seriously, and it is to be hoped that when full publications of Zarechnak's ideas become available, a useful contribution will result.

The Bureau of Standards has already been mentioned as one of the active institutions in the field of machine translation. Franz Alt and Ida Rhodes jointly contributed a paper on the recognition of clauses and phrases in the machine translation of language. Unlike some of the papers this one was very well written and understandable, a pleasure to read. It suggested a simple algorithm which enables the machine to decide when clauses start and when they finish, and also to see if any clauses are left incomplete at the end of a sentence, in the latter event, of course, the machine returns to the beginning, and repeats its analysis *via* a different route until a correctly terminated sentence is obtained. The paper, apart from its valuable idea content, contained a detailed analysis devoted to Russian and gave numerous examples both in Russian and in English.

The United States Air Force, well known for its support of machine translation, and for its construction of large-scale dictionary mechanisms, produced a paper by Murray E. Sherry on the identification of nested structures in predictive syntactic analysis. The idea of nested structures was illustrated earlier in the work of Parker-Rhodes. Sherry's contribution showed how, by the use of certain sentinel words, clause determination could be, assisted and predictive analysis rendered more simple.

L. R. Mickelsen (I.B.M. Corp., U.S.A.) considered source language specification with table look-up in a high-capacity dictionary. He discussed the well known idea of a dictionary containing words with associated structure numbers originally defined in the work of the Birkbeck College group. His contribution was to apply this idea, explained in detail originally for French-English, to the combination Russian-to-English.

Continental contributions

Of the European workers, the University of Milan provided a strong contingent. Silvio Ceccato and Runa Zonta, of the University of Milan, attempted an analysis of how humans go about translation in a paper entitled 'Human Translation and Translation by Machine'. Such an analysis of human mental processes is quite

likely to form a basis for any large-scale work on machine translation, and the work of Ceccato and Zonta will be read with interest by all workers in this field.

From Paris, P. Meile considered problems of address in an automatic dictionary of French. His paper described an attempt to economize dictionary space by giving the first N letters of a word (he suggested the value $N=6$) plus the total number of letters, or a terminal letter or the ending itself. Such ideas for word length compression are, of course, quite old. They were used both at Birkbeck College and in the Russian work. On the other hand, the particular scheme suggested by Meile has certain attractions, and merits consideration.

M. Corbe and R. Tabory (I.B.M., France) described an introduction to an automatic English syntax by

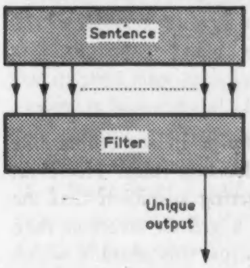

Fig. 2

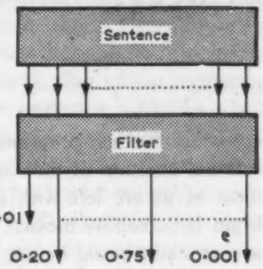

Fig. 3

fragmentation. This contained an interesting analysis of the proportion of unambiguously recognizable parts of speech of the words in a text. The paper provided numerous statistics, drawn from a sample containing about a thousand words, and the fact that, on average, something like one third of the words are grammatically ambiguous will come as a surprise to many people who have not been familiar with this problem in practical experiments on machine translation.

Probably the most interesting of all of the European contributions was that by Y. Lecerf, from Euratom, His paper, entitled ' Intrinsic Machine Addressing in Automatic Translation ', contained an analysis of the difficulties of using structural information. He considered the example:

Le	**page**	**brise**	**la**	**pointe**	**de**	**la**	**lance**
Art.	*N. fem.*	*V*	*Art.*	*V*	*Prep.*	*Art.*	*V*
Pr.	*N. masc.*	*N*	*Pr.*	*N*		*Pr.*	*N*
			N			*N*	

This example has, considering the possibilities of arranging the different parts of speech in the order of words, $2\times2\times2\times3\times2\times1\times3\times2 = 288$ possibilities. He suggested, first of all, that the correct member from this set of possibilities might be found by an automaton having the structure shown in Fig. 2. This is unlikely to be practically useful because of the complexity of the filter, which has very many inputs and a single output. Furthermore, it is unlikely that for even simple sentences the filter would give an unique output. What is really needed, Lecerf pointed out, is a filter which gives the possible outputs and accompanies these by the probabilities that they are the true output. This idea is shown in the filter diagram reproduced in Fig. 3. Unfortunately, for practical reasons, this scheme, too, would be unworkable because of difficulties in constructing the filter, so that a set of sub-filters, each dealing with a part of the sentence which can be treated by itself, was substituted, which fed a full filter giving the correct probabilities. This discussion of filters is interesting in itself, but Lecerf's long paper went on to discuss certain topological analogies between language and the geometry of curves, and suggested that the idea of the intrinsic equation of a mathematical curve might provide a clue to an invariant description of language.

British work

We come now to the British contributions. There was a paper from the National Physical Laboratory by D. W. Davies and A. M. Day on a technique for consistent splitting of Russian words. This contained a detailed analysis of the stem-ending decomposition process, described in terms suitable for application with the National Physical Laboratory's version of the Harvard dictionary and the N.P.L. computers Ace to Deuce.

A second paper from N.P.L. was that by J. McDaniel and S. Whelan on the grammatical interpretation of Russian inflected forms using a stem dictionary. The title of this paper is self-explanatory but it is worth remarking that the paper formed a distinct contribution to the detailed linguistic literature of this subject, and will undoubtedly be of considerable use to all those who deal with Russian to English translation by machine.

Birkbeck College was represented by a single paper read by Michael Levison, on the mechanical analysis of language. This described some actual machine applications to glossary construction and letter-group frequency analysis. It then proceeded to analyse the efficiency of different methods of list construction by computer, an important topic since, even at the present time, computer storage is relatively limited, and the time wasted if lists of words have to be displaced for the insertion of new data can be considerable.

Summing up

The conference discussions were stimulating and often heated. Nevertheless, this conference can be counted a distinct success. The papers presented, and also an edited version of the discussion, will be published in due course by the Stationery Office. All workers in the field who did not have the pleasure of attending the conference will certainly wait with considerable anticipation for the production of this volume.

The organizers of the conference are to be congratulated upon this smooth-running piece of work. Perhaps the fact that the Chairman was Albert Uttley, Superintendent of the Autonetics Division of N.P.L., and well known for his work on self-optimizing automata, may be a reason for this good organization, for surely, if Uttley can construct a self-optimizing automaton, he must indeed be self-optimizing himself. And, this being the second of such conferences that he has organized, shows that he lives by his own precepts.

Differentiation of cybernetics has continued, and cyberneticians no longer behave like out-of-place engineers, biologists, or logicians

Cybernetics *becomes well-defined science*

by **GORDON PASK** M.A., M.N.Y.A.S.
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A GLANCE AT THE PROCEEDINGS OF THE FIRST CONGRESS of the International Association of Cybernetics will convince you that five years ago almost anything counted as cybernetics. Papers about detailed problems in automation, computer technology, servo-mechanism theory, rubbed shoulders with contributions from fields like biology, sociology and logic. Three years ago, at the second Congress, the more outflown branches had been pruned away. At the recent meeting, held in Namur under the presidency of Professor Georges Boulanger, it was obvious that differentiation had continued, and that, as a result of it, cybernetics has gained the status of a well-defined science.

It is, of course, an interdisciplinary science, so that papers presented by cyberneticians are rightly diverse. Like applied mathematics, cybernetics cuts across the academic boundaries. Only nowadays automation, biology and logic are considered from a common viewpoint, and, for the most part, people have ceased to speak like out-of-place engineers, biologists or logicians.

There were four general lectures: on the industrial consequences of cybernetics (M. Georges Villiers); on cybernetics and biology (Dr Henri Laborit); on information measures (M. François Bonsack); and on evolutionary systems (myself). As the remaining 98 papers were delivered in five parallel sessions, it will only be possible to review an arbitrary selection of these and to indicate the flavour of the proceedings, which will be published after about a year.

Basic ideas about mentality in brains and life in cells

In a paper entitled *The brain and the computer*, Dr W. Ross Ashby set out to dispel a number of myths that hamper our consideration of intellect. Few, nowadays, would seriously contest the view that some form of intelligent activity can be carried out by computing devices. There is obviously a good sense in which suitably programmed machines can solve problems, make decisions, and, so far as they are permitted to construct further programs, indulge in something like rational creation of their own decision rules. However, most of us are left with a lingering suspicion that the brain is somehow blessed with a greater freedom than any machine could be, and it is just this attitude which Dr Ashby contradicted. He pointed out that the computer has far more freedom than the brain. The brain is restricted by all manner of constraints built into it by its inheritance, its maturation, its environment, indeed by the character of the materials from which it is constructed. The peculiar characteristics of a brain that give us the impression of freedom occur in particular because the functional topology of the brain is well suited and similar to the functional topology of its environment. Because of this, brains are very efficient problem-solvers for the limited category of problems in which the elements are described by continuous variables. Thus, for example, brains solve mechanical problems very well indeed, simply because mechanical problems have continuity and symmetry in Euclidian space. A computer may, of course, be programmed to do likewise. It would be programmed in this way to solve differential equations, and the program in this case adheres to what we know of brain-like logic. But the point is, it need not be programmed in this way. The computer is the first really blank cheque available to behavioural science. In it we can simulate rational activities which are entirely unconstrained. Professor Ashby has already investigated this field, and his researches are continuing. One fact which emerges from them is that brains and computers alike are subject to the law of requisite variety. The originality needed to meet the unusual, when it occurs in the environment, comes from variety introduced into the system by way of chance trial. Learning by trial, overt or internal, should not be despised.

This paper illustrates the cybernetic method of constructing models of abstract systems that can be identified with various physical organizations, like a

brain (as in this case), or a society, or the parts of an animal. The complementary approach is to construct a control theoretical model to analogize a specific entity or set of observations. This method was typified in Dr Laborit's general lecture, in which he demonstrated an isomorphism between cellular metabolism and certain assemblies of feedback loops. The essential thesis was that the stability of a living cell is maintained by feedback controllers (the information transfer commonly occurring by interactions at a biochemical level between enzyme-catalysed cycles of chemical transformation). This sequence of cycles is necessary in order to synthesize and preserve the physical structure of the cell and the physical basis for energy transfer. But the same structure also mediates the regulation, for the metabolic cycles depend upon its existence. So, in a certain sense, the controller, which organizes the cell, is responsible for its own survival. The overall plan of the regulating system is hierarchical. In this respect it is like an adaptive controller, which can be built from comparable units acting at different levels in an hierarchy wherein units at a higer level modify the parameter-values of units acting at a lower level. Joseph Polonsky has been developing a closely related set of concepts over the last few years, but at a quantum-mechanical rather than a biochemical level, and he is led to regard the entire cell as being in a certain, well defined way a gigantic macromolecule. This point of view is indicated in Polonsky's paper, *La cellulè vue comme un système cybernétique naturel à la lumière des récents progrès à l'électronique moléculaire.*

The logic of systems

There were numbers of papers on the logical foundation of cybernetic ideas. Professor Eckmann, in collaboration with Professor Mesarovic, gave an interesting discussion *On some basic concepts of general systems theory.* Professor Beth spoke on *Aspects Semantique des systems formale.* M. Detont and Leroy presented a largely theoretical discussion entitled *Elaboration d'un program pour l'analyse de la signifaction.* Their work has been mainly directed towards document retrieval from a scientific library. Their contention is that adequate search procedures rest upon a well defined hierarchical structure wedded to invariant rules of procedure, together with some continuously changing logical rules that are adaptive in the sense that they depend upon experience of demands made during the operation of the retrieval automaton. Perhaps the most interesting of all these papers was delivered by Professor Apostel, *Learning mechanisms and the foundation of logic.* Professor Apostel first pointed out some of the basic dilemmas existing in the present-day interpretation of logical systems. Starting with the propositional calculus, he drew attention to Kolmogroff's interpretation. By extending this, and equating a calculus with a machine constructed to realize a calculus, we may regard a logical problem as a program to produce programs. Thus we may have programs that produce programs to solve the original problem, to replicate the problem, and so on, and these forms are descriptive of logical connectives. Some effort is made to obtain an axiomatic description of the *concept* of a digital computer, as the vehicle embodying these programs. It is pointed out that inductive and probabilistic logics entail the notion of a computer capable of 'learning', where the word 'learn' is used in an unusually broad but well specified manner.

Finally, Bernard Chapman introduced a sadly needed notation for describing the activity in an 'adaptive' network in terms of matrices.

Another group of papers were concerned with more specific aspects of 'artificial intelligence'. Vincent Giuliano described a very interesting pattern-recognition system, 'a Gestalt method of automatic pattern recognition' inspired by studies of octopus vision. An image of the same pattern—for example, some alphabetic character or a figure—is projected, coincidently, upon a number of different receptors. Each receptor is furnished with only one photo-sensitive element. But the image which falls into the receptor may be passed through various kinds of optical density wedge before the summated light falls upon the photo-sensitive device. (In the absence of any wedge, a photo-receptor registers simply the mean luminosity of the figure, and in this connexion it is convenient to think of a luminous figure upon a dark background.) The optical density wedges define two-dimensional density functions covering the pattern area, and are chosen in relation to parameters such as 'the centre of gravity' of the pattern. These functions are used to render an output signal, derived from operations upon signals emerging from each of the different photo-receptors, invariant with respect to irrelevant variations of the pattern to be recognized, such as translation, rotation, and changes in illumination or minor discontinuities. Thus, for example, if the output of any photo-receptor is divided by the output obtained from the receptor which has no wedge, and which registers the overall intensity, the resulting signal will be invariant with respect to variations of intensity of illumination of the pattern. Briefly, then, the separate signals, after operations of this kind, are used to produce a numerical output which is a functional computed upon the set of possible patterns, and recognition is achieved by comparing this numerical output with a set of numbers representing the patterns that the machine is designed to detect. A best-fit procedure between the value of the functional and the reference numbers is used for the recognition of distorted patterns. A mechanical realization of this system is small and moderatively inexpensive.

There was also a number of papers dealing with automata. At one extreme, M. Le Lionais spoke of chess playing and other heuristic automata, *Les jouers des écheques automatique,* whilst at the other very

practical extreme, Kovnat and Bertucelli described *A program optimizing perceptron for closed loop application*. This perceptron-like network is used to modify and optimize the program of an existing computing facility, rather than compute directly. In the case described, this facility is an information-routing program, used in connexion with satellite control, that determines the access of input and display devices to an accumulated-data register. The optimum program depends greatly upon the required form of access and very considerable advantage is gained if the routing program can be modified to fit unexpected requirements. The perceptron is required to recognize features or 'percepts' in the input data and to associate these with operations upon the program. Consider a set R of possible 'adjustments' r. Suppose that in the course of a 'training' or reinforcement procedure, which is conducted before the perceptron-like network is actually connected into the system, a 'training' situation characterized by input-data feature A has been induced to make adjustment r_1 by making this adjustment occur and reinforcing the coincident occurrence upon many different occasions. If, in real life, situation B occurs, and if A and B are similar, in the sense pertinent to a perceptron, then r_1 should be elicited. The authors demonstrate cases in which such a network will elaborate cogent relations of similarity and indicate that the system would be passably efficient in these cases. Further, it appears necessary to have such adaptive parallel computation for the practical realization of already projected satellite systems. Although there are many difficulties that bedevil the specification of such networks, and although their function is ambiguous, this paper is of great interest as one of the first well worked-out proposals for the application of these systems.

The brain

The next set of papers concerned mechanisms in the brain. Professor Napalkov, who is co-author of the recently translated *Problems in neuro-cybernetics*, presented an authoritative discourse, *Systematics in the working of the brain and some problems in cybernetics*. Frank George, in *Analogues of thinking*, considered the brain-like interaction of decision-making automata. Suppose these are represented by a pair of programs in a computer capable of elaborating suitable decision rules by adaptation. It may be that, after some interaction, we, looking on externally, observe that the decision makers have identical transfer functions and are responding in the same way to each other's activity. But George points out that, even if this is so, the internal organizations which have been built up may be vastly different, and he develops this concept in terms of the maturation of brains and the detailed processes that underlie statistically similar forms of behaviour. Professor Tou described *Digital control concepts for nervous system synthesis and simulation*. Various parallel, organized simulations of brain-like processes will 'learn' by building up, from experience, expectation functions and utility functions, and will make decisions which maximize the expected utility. An interesting feature of his discussion lay in various serial and partitioned procedures, which avoid the prohibitively large number of elements needed by a parallel realization. Professor Boc, in *Recognizing learning and anticipation in the vacuole memory theory*, described the intruiging and relatively little publicized ideas underlying this theory, which suggests that the interfibriliar vacuoles amongst the nerve fibre in the grey substance of the nervous system act as analogue threshold discriminators.

Machines that imitate and interact with a man

Finally, there were papers on the interaction between man and machines of one kind or another. The most interesting of these was a discussion by John Clark on *Induction of hypnosis*. First of all, Clark gave what must be one of the most objective accounts of the behaviour evidenced by hypnotist and subject, in various ages when the art was practised, from Mesmer onwards, and using various techniques. He then pointed out that, apart from certain special procedures, such as suggestion, which are ancillary to inducing the hypnotic condition, the behaviour of the hypnotist could be mechanized. Its mechanization does involve feedback from the subject, and although the channels of feedback may change (or at least, their significance may change) in the course of induction, the changes are well determined as a function of the joint behaviour. Briefly, a proposed model of the process implies that the induction of hynosis entails directing the subject's attention to commonly autonomous activities, such as the reflexes involved in breathing, and thus the process builds up 'uncommon' feedback loops. The condition is maintained by an 'adaptive' automaton standing in the place of the hypnotist. A psychiatrist, Eric Thonhammar, spoke, in more nebulous but interesting terms, about the relation between a psychiatrist and a patient. There were numbers of papers dealing with adaptive teaching machines that imitate a real-life instruction, and finally Lucien Mehl discussed the related problem of aesthetics in *L'art non figuratif et la théorie de l'information*.

Growing interest

Although most of the participants were from Belgium and France, there was a fairly broad international representation from America, Britain, Czechoslovakia, Germany, Hungary, Italy, Poland, Russia, Spain and Yugoslavia. Obviously there is a growing interest in cybernetics. The strength of the Association is increasing, and proposals to introduce continuous translation and better documentation should add to the usefulness of the next Congress, which is to be held in a couple of years.

Production control and machine loading in a jobbing shop

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The de Havilland Aircraft Co. Ltd

PART 2

Shortage control and the statistical method were discussed last month. Below, the author concludes his remarks on the deterministic approach, and goes on to propose a scheme for two-stage planning

Faced with these astronomical numbers, even in the simplest case, it is obvious that a method is needed that will enable one to reach the optimum schedule through a series of successive steps or approximations not prohibitive in volume. Such methods do exist for two- or three-stage processes. In other words, if the number of operations per part is not greater than three, it is possible to find the optimum schedule (optimum according to criteria much simpler than (5)) without the necessity of going through all possible sequences; the latter are astronomically numerous even in this case. However, the method has not been extended to the general case of N operations per part. It must be understood that the above constitutes one of the great problems of combinatorial analysis, and speedy progress cannot be expected. Consequently, though this avenue of approach seems to be closed at the moment, it has not been proved yet that the solution does not exist, and it would not perhaps be unreasonable to expect the answer in the future. Yet, after closer scrutiny, it appears that the answer, even if found, would be of little practical value. First of all, the data required are not known with sufficient accuracy, and never will be. All machining times, setting times, movement times, are only approximations to the true times, even if everything goes well. The calculations would be based on existing orders, and acceptance of new orders would require a complete re-calculation of the optimum schedule. The schedule, once established, would have to be most rigidly adhered to, and, if upset, it would require re-calculation. This seems to ask a bit too much of the computer, and it would be economically unjustified in almost every case. It must be always remembered that the cost of necessary data processing is in itself a factor to be included in an appraisal of any scheme.

To make such a completely deterministic schedule more realizable, a fantastic amount of all the possible factors one could think of has to be taken into the initial calculations, swelling the amount of computing. Every departure from the plan, even the smallest, would have to be signalled back to the centre, thus placing enormous demands on the internal communication system. Further, in the presence of the innumerable disturbances (which could never be completely foreseen, and only, at the best, described statistically), the schedule satisfying (5) optimally under the purely deterministic assumption, would not be truly best, even theoretically.

To make this clearer, suppose we have two schedules: one economically the optimum (provided it is rigidly adhered to, and very likely to result in tremendous bottlenecks and long delays if anything departs, even slightly, from the plan); the other schedule inferior economically, but less sensitive to disturbances. The second schedule is always preferable, not only on a common-sense basis, but also demonstrably, by strict mathematical analysis. So the method of scheduling has to take the probability distributions of disturbances into account. No method exists of combinatorial analysis of large-scale problems in the presence of stochastic noise.

Another method of deterministic planning is based on priorities only. It is recognized here that unforeseen events will quickly upset any rigid schedule of considerable time-lengths, and, consequently, no attempt to devise such a schedule is made. Still, the shop is run on an entirely deterministic basis, in the sense that the order to perform any machining operation on a given machine, and at a given time, is always issued by the controlling centre. This is done in the following way: every time the machine-tool completes an operation, the controlling centre is immediately informed. In every case, there are only limited numbers of batches which are ready to go on this machine. One of the batches is chosen by a system of priorities, based essentially on (5): but this system is not to be recommended, because it places terrifying requirements on the controlling centre's information storage, computational speed, and communication system. Also, and this is even more im-

portant, it does not establish the *definite* target-date for any substantial period in advance, and, as we remember, this shortcoming was one of the main reasons for rejecting a statistical approach.

PROPOSED METHOD

Having satisfied ourselves that there is no complete mathematical solution to our problem, let us now suggest a line of attack which would lead to fruitful results.

We start by stating the obvious truth, that the further we plan into the future the more likely our plans are to be upset by unforeseen disturbances. Hence, the degree of detail in planning should decrease with the length of time-period covered. It is, therefore, proposed to divide the planning into two stages: long-term and short-term.

Long-term planning

The aim of long-term planning is to provide a broad and approximate schedule of manufacturing activities to satisfy the customers' orders. The period to which planning will extend is determined by knowledge of orders received and by availability of relevant data referring to: break-down of the final product into sub-assemblies and finished parts, to the raw materials and tools required, to the machining operations to be performed, etc.

While the human planner can often concoct some sort of approximate (but widely-off-the-mark) schedule on very scanty information, the present-day automaton requires definite data, strictly specified in kind and quantity, to do any planning at all. The availability of all files covering every order to be included in the production plan is a *sine qua non* of the proposed system.

The increased stringency on timeliness in preparation of technical data will of course be compensated many times over by relieving production control from the overwhelming burden of converting this technical information into detailed scheduling of manufacturing activities. If, for some good reason, machining has to be started before the files are available, the job has to be included in the same category as certain work which cannot be planned (e.g. small internal orders) and assumed to be accommodable within spare capacity left for that purpose.

The long-term planning will begin with computing the total net requirements for b.o.f.s and m.h. sub-assemblies and parts, arising from all the customers' orders taken into account. Using now fixed time-cycles for assembling work and reverse scheduling, the latest completion dates compatible with delivery dates will be determined for assemblies and sub-assemblies. Then the actual work on a given assembly may be shifted to an earlier period, according to the load on the assembly shop. It has been assumed here that the assembly labour is highly interchangeable, and the capacity of the shop for the given type of assembling depends mainly on the number of jigs usable only for this type of assembly. Hence, there is no competition between the products for the use of existing facilities, which is the root of the difficulties in scheduling the machine shop. The problem of adjusting the load to the capacity of the assembly shop is much easier here than in the machine shop.

The starting date for assembly will determine the completion date for component parts, which must be ready earlier by a certain fixed interval. Although, strictly speaking, not all parts are needed at the beginning of assembly work, as some of them are fitted during the later stages, it seems safer and simpler to assume that all components should be completed some time before the beginning of this work.

The parts will then be batched with identical parts required for other orders within a similar time period. (The detailed investigation into economical batch-size and scrap allowance is outside the scope of this article. It may be mentioned, however, that scrap allowance will depend on: number of operations, whether the part is a key assembly part, how difficult it is to make, how costly, etc.) Each batch is characterized at this stage by length of time-cycle and amount of work in each machine class to be performed within each monthly period *without* specifying a more detailed sequence of operations. Using this information, the machine load will be computed in terms of the total number of hours required in every machine class in each period. This will be compared with available machining capacities, assuming certain levels of machine utilization. The optimum allocation of resources to existing facilities by linear programming has little chance of realization here. This is because the allocation, in order to be useful, would have to be at batch level. Unfortunately this increases the number of variables to unmanageable proportions in the case of a large jobbing shop. The allocation of machining resources project-wise would be of little value, as it would imply strictly parallel progress in time on all parts belonging to this project. The most one can do at this stage, if the capacity in a certain period for a given machine-class is over-stepped, is to shift the whole batch automatically according to rules yet to be found. The 'stretching' of time-cycles would allow additional flexibility in planning, but it might be too complex computationally.

Admittedly, time-cycles and machine utilization both depend on the efficiency of the method of short-term machine loading, and their values, assumed in the long-term planning, will have to be compared eventually with average times actually achieved. It is proposed to readjust the long-term plan at fixed intervals, in accordance with achievement and new orders. It may be possible to fix a certain percentage limit for discrepancy between the plan and the achievements in machine classes, and reschedule only if this limit is exceeded. The limit itself would presumably be a complex quantity (e.g. if the limit were exceeded only in one machine class one would, presumably, rather subcontract than reschedule everything).

To be continued

Pick-off

by 'UNCONTROLLED'

SIR GEORGE THOMSON (who was the first President of the S.I.T.) has permitted the Society to use his name for an annual lecture. Properly enough, Sir George delivered the first Thomson Lecture himself. He took *The inspiration of science* as his title, and jostled his hearers gently in a number of ways. For example, he allowed that Lord Kelvin had been correct in extolling the importance of measurement, but went on to say that —in the last resort—everybody is trying to do something qualitative. I think Sir George has made a profound point here, but how many engineers—and especially instrument engineers—will admit it? Most of us are too busy with the affairs of the moment to realize that our means are (in the *last* resort) for qualitative ends. It was healthy for the S.I.T. to hear this said.

A QUICK LOOK at the recent packaging exhibition at Earls Court suggested to me that few of the exhibits were radically new. Packaging is one of those arts which did not feel much of the impact of the 'automation' revolution, high-speed automatic machinery having been commonplace in this field for many years. Mechanical development to meet the demands of highly competitive consumer-goods industries has been steady rather than abrupt.

One noticeable result of the automation era has been the introduction of electronics in this field, though it is surprising how slow this introduction has been. Users of packaging machinery have been obviously reluctant to accept electronic gadgetry. Their reason, I gather, is that they regard electronic equipment as unreliable. Equipment for the consumer-goods industries, particularly if it is not directly productive, generally has to be built down to a price, and this certainly does not make for reliability. Nor do the users treat the equipment as they should. I heard of one food manufacturer who insisted on washing down an electronic box daily with a high-pressure hose.

I overheard a more surprising criticism of electronics, though: 'They do not work fast enough'. This may come as a bit of a surprise to electronics people in the data processing field, who are accustomed to making this very taunt about mechanical devices. The remark I heard was made in connexion with electronic check-weighers for packaged goods, and there is some truth in it. The speed of these devices is usually around 100 checks/min, so they do seem to lag behind the packing machinery they are intended to serve. One checker on show, of American origin, was claimed to operate up to 300/min, but even this would be too slow for canning, where filling and sealing machines now exceed 400/min.

No doubt the manufacturers of check-weighers, who mostly have an electronics background, would claim that it is the mechanical side of the equipment which slows them down. Nevertheless I feel higher speeds ought to be possible. Is the mechanical problem really more difficult than that of sealing the end on the filled can? I have not studied it in detail, but somehow I don't think it can be.

THE B.C.A.C. is 'loosely' organized in the best possible sense, said its Chairman, Sir Walter Puckey, last month. He was introducing Dr D. G. Christopherson to an audience of roughly a hundred people, who had turned up at the I.E.E. to hear the first annual lecture of the B.C.A.C. Sir Walter's quip raised an appreciative laugh, but there was a faint undertone of disillusionment in it. Since B.C.A.C. was 're-organized' about a year ago, it has sponsored one major national conference* and Dr Christopherson's lecture. No doubt there has been much committee business behind the scenes, but it is difficult to see what has been achieved beyond the arrangement of these two meetings. My own feeling is that B.C.A.C. is still failing to make an impact at the practical level. While the doings of the professional institutions sometimes manage to give an impression of immediacy, B.C.A.C.'s attitude makes it look like an Upper House, aloof from day-to-day legislation and the emergencies of real life. I have not yet heard of anybody who has turned to the B.C.A.C. for advice, help, or guidance.

* *Automation—men and money*, reported in last August's issue of *Control*—EDITOR

DR CHRISTOPHERSON made some good points in his lecture. His title (not entirely of his own choosing) was 'Mathematics—friend or foe?', and he thought that the answer to that question depended very much on the education of the engineer who was asked. Sir Walter Puckey had remarked that mathematics has many foes and needs more friends, and Dr Christopherson did his best to win them—though unfortunately, on this occasion, from an audience of the already amiably disposed.

As Vice-Chancellor of Durham University, Dr Christopherson was of course much concerned with the educational side. He suggested that in the British system too much emphasis is put on mathematics as a means to various ends, and not enough on the importance of mathematical understanding as part of the equipment of a trained mind—mathematical knowledge is as vital as hardware knowledge to the control engineeer. Dr Christopherson went on to argue that no parallel should be drawn between the policy of choosing readily realizable designs and the policy of using only already-comprehended mathematical methods. To illustrate the error of this, he recalled his own youthful attempt to linearize an essentially non-linear instrument in order to calculate its response. Haven't most of us had this sort of experience? Yet the difficulties remain.

AN AMERICAN FIRM, Auerbach Electronics Corporation, has dropped the 'electronics' from its name. The object is to 'remove the semantic limits to broadened corporate activities in all aspects of information sciences and technology'. This is quite a refreshing approach—not many engineers that I know would acknowledge that 'semantic limits' exist, let alone act on the thought.

A monthly review — under basic headings — of the latest control engineering developments for all industries; especially edited for busy technical management, plant and production engineers, chemical engineers, etc., who are interested in instrument and control systems

IDEAS APPLIED . . .

. . . to SWITCHING

Voltage-sensitive relay

by E. J. BISHOP, Advance Components Ltd

A new method of closing and opening relay contacts at predetermined a.c. input voltages has recently been introduced by Advance Components Ltd. The equipment comprises essentially a special type of constant voltage transformer operating a standard Post Office type 3000 relay. The device is completely static (apart from the relay), and besides permitting accurate control of the 'relay close' and 'relay open' voltages, it allows adjustment of the differential between them. The 'relay close' voltage is preset during manufacture, and the differential can be adjusted as required by a potentiometer control. The unit fulfils many of the duties at present performed by the various types of calibrated relays, such as voltage or current control, motor protection, machine tool control *etc.* An advantage of the method is that the relay is always fully energized or de-energized, thereby maintaining good contact pressure under vibration conditions, and fluctuations in supply voltages.

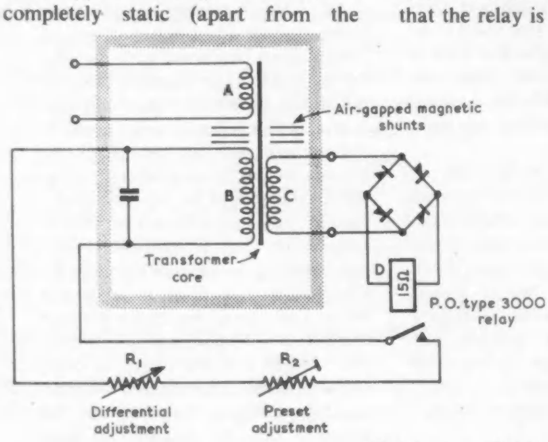


Fig. 1.1 (Left) Basic circuit of constant voltage transformer used as a voltage-sensitive relay

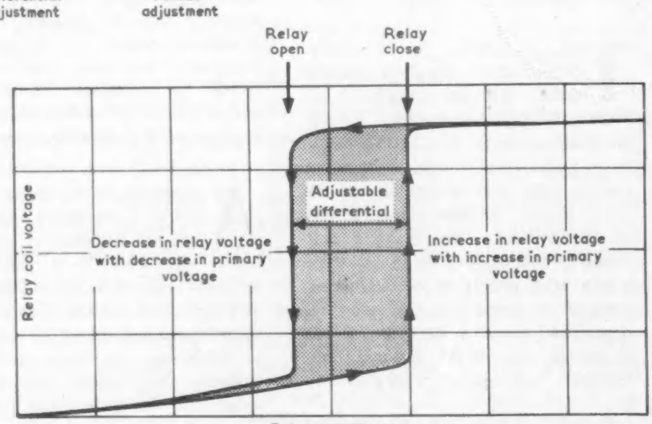


Fig. 1.2 (Below) Characteristic curve of voltage-sensitive relay

The Advance constant voltage transformer is basically a combination of a resonant electrical circuit and a high leakage-reactance magnetic circuit. There are four windings in the electrical circuit, as shown in Fig. 1.1. These are the three transformer windings (the primary, *A*, the resonant winding, *B*, and the secondary, *C*) and the relay winding, *D*. The primary winding is isolated from the resonant and secondary windings by magnetic-shunt paths incorporating air gaps. When a low a.c. voltage is applied to the primary winding, the magnetic flux produced in the core induces a voltage in the resonant winding which is roughly proportional to the primary voltage, the ratio of the voltages depending on the numbers of turns on the two windings. At this stage the reluctance of the magnetic-shunt path is high compared with that of the magnetic path through the resonant winding.

As the voltage applied to the primary winding increases, the core flux increases accordingly, thereby changing the inductance of the resonant winding, and the circuit swings into ferro-resonance. At this point the voltages across the resonant and secondary windings rise very rapidly to a predetermined and stable value. The magnetic circuit is so designed that this sudden increase in the resonant winding voltage, with its resulting increase in magnetic flux, causes the resonant section of the core to saturate. It follows that the reluctance of the saturated core section increases, and becomes higher than the

reluctance of the magnetic shunt path. The magnetic shunts now carry any further increase in primary flux, and the only flux flowing in the resonant section of the core is that required to supply the losses and to maintain resonance. (This condition corresponds to the normal function of the constant voltage transformer, the output being taken from winding *C*.) The sudden increase in voltage caused by the swing into resonance can be brought about by an input change of only $\frac{1}{2}$% of the nominal supply voltage (see Fig. 1.2). For the voltage-sensitive switching application, the secondary winding is designed to give an output suitable for operating a Post Office type 3000 relay, *via* a bridge rectifier.

The sudden increase in voltage across the secondary and relay windings closes the relay contacts, thereby connecting the resistors R_1 and R_2 in parallel with the resonant winding. This modifies the point in the characteristic at which the unit drops out of resonance, and reduces the differential between 'relay close' and 'relay open' voltages. The input voltage setting at which the secondary voltage rises, and the relay contacts close, is controlled by the initial design of the resonant circuit, and by adjustment of the magnetic circuit during manufacture. The resistor R_1 can be varied to adjust the input voltage at which the sudden decrease in secondary voltage occurs, thereby opening the contacts. The preset resistor is incorporated to prevent oscillation which could occur if the unit was adjusted with a 'relay open' voltage higher than the 'relay close' voltage.

Accuracy within ±1% of the 'relay close' and 'relay open' voltages at a fixed frequency is obtainable, and any normal combination of relay contacts can be fitted. Adjustment of the differential control permits any 'relay open' voltage to be selected between 75% to 100% of the nominal 'relay close' voltage. The equipment could be designed to operate at any reasonable input voltage, and any power-system frequency. A unit similar to that described has been produced in large quantities, and employed in coal mines. This particular unit was designed in conjunction with the manufacturers of the mining equipment, to operate a contactor in the gate-end switch-gear. In this application intrinsic safety and reliability are of primary importance.

IDEAS APPLIED . . .

. . . to TENSION

Carbon pile as tension controller

Where such materials as wire, tape or film have to be wound on reels at high speeds, control of the tension in the product is often required to guard against breakage or other damage. If the reel is driven by a constant-speed motor, tension increases with the diameter of the material on the reel, and winding speed is limited to that permissible at maximum diameter.

To overcome this difficulty, Newton Brothers (Derby) have produced a simple tension-measuring device, based on a carbon pile, which regulates the speed of winding to maintain a predetermined tension. The schematic arrangement and circuit are shown in Fig. 2.1. The force exerted on the pulley, which is proportional to tension, is applied to one end of a carbon pile, the other end of the pile being fixed. Electrically, the pile is connected in series with the armature and field windings of the d.c. series motor which drives the reel. The pile, which consists of a number of carbon disks compressed together by the force exerted by an internal spring, increases in electrical resistance as this compressive force is decreased. Thus an increase in tension in the material being reeled produces an increase in the resistance in series with the motor armature. The voltage applied to the motor, and its speed of rotation, are therefore reduced by an increase in the tension in the product. The compressive force exerted by the spring in the pile may be varied, giving adjustment of the desired value of the tension.

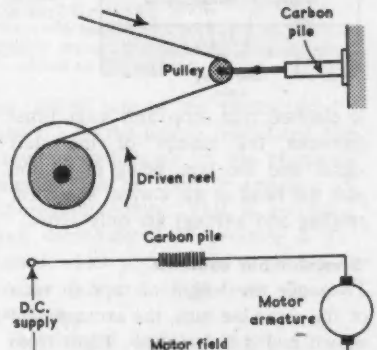


Fig. 2.1 Schematic arrangement and circuit for carbon pile used as tension controller

Used in the simple manner described here, it is claimed that the device will hold tension within ±2% of the desired value, and that very little maintenance is required. The unit was originally developed for an application in the manufacture of cinematographic film (see Fig. 2.2).

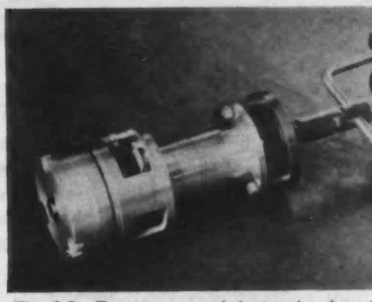


Fig. 2.2 Tension control device developed for film-reeling application

. . . to TAPE DRIVES

High-speed pneumatic clutching and tape-reservoir contents measurement

A number of interesting features have been incorporated in the tape-drive mechanism of the new Decca 4000 computer tape unit, in order to achieve very high speed 'start' and 'stop' operations.

The general arrangement of the mechanism is conventional, as shown in Fig. 3.1. The capstans *A* and *B*, which control the movement of the tape past the read/write head *C*, rotate continuously in opposite senses. By means of a pneumatic clutching arrangement the tape is driven by either *A* or *B*, as demanded by the computer. Ample lengths of tape are stored in the 'scramble bins' *D*. Thus the masses to be accelerated when the tape starts, stops, or reverses are small. The bins are replenished from the

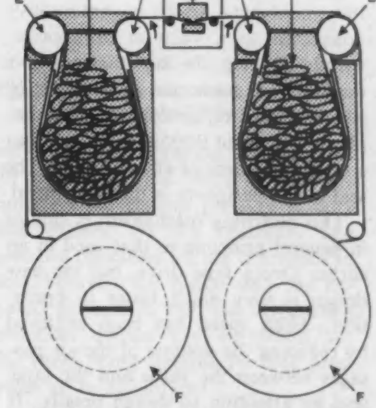


Fig. 3.1 Layout of complete tape drive

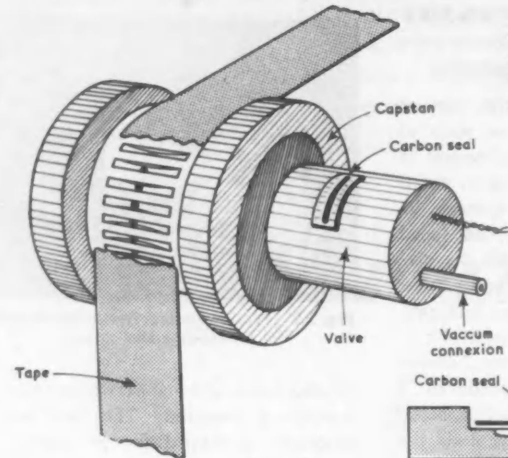
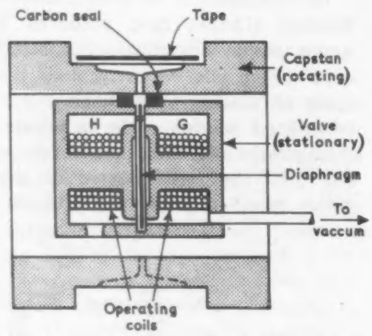


Fig. 3.2 (Left) General arrangement of tape and electropneumatic valve (valve withdrawn from capstan)

Fig. 3.3 (Below) Schematic cross-section of capstan and valve



spools F by further pneumatically-operated capstans E, the spools being driven directly by high-resistance squirrel-cage induction motors. Spool-motor control is by three-level measurement of the bin contents, using a photo-electric method.

Pneumatic clutching

The system for giving rapid starting and stopping of the tape is illustrated in Figs. 3.2 and 3.3. Slots are cut in the surface of the capstan on which the tape runs, and radial holes connect the slots to the inner surface of the capstan. To drive the tape, the slots on the part of the capstan in contact with the tape are connected to a vacuum; to release the drive, the connexions to the slots are opened to atmosphere. Connexion between the continuously-rotating capstan and the control valve is through a carbon seal.

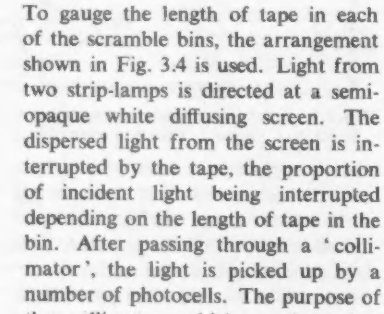
Operation of the valve is electromagnetic, a Permalloy diaphragm (see Fig. 3.3.) being attracted to one side or other of the central annular groove in the valve body. When the diaphragm is in the left-hand position, the slots in the capstan are connected to the chamber G, which is continuously connected to a vacuum of approximately 22 inHg. In the other position, the slots are connected to chamber H, which is open to atmosphere. The diaphragm is about 0·005in thick, and has a total movement of about 0·007in. The seal at the periphery is metal-to-metal.

This clutching mechanism is similar in general principle to that used in an earlier Decca tape drive, but the new design is very much faster in operation. High speed has been achieved by reducing the volume of the air passages between the valve and the tape, and by attention to design details. It is claimed that stop and start times (between the receipt of the start signal and the tape being in motion past the head at the correct speed for reading and writing) are only 1½ms.

'Scramble bin' contents

To gauge the length of tape in each of the scramble bins, the arrangement shown in Fig. 3.4 is used. Light from two strip-lamps is directed at a semi-opaque white diffusing screen. The dispersed light from the screen is interrupted by the tape, the proportion of incident light being interrupted depending on the length of tape in the bin. After passing through a 'collimator', the light is picked up by a number of photocells. The purpose of the collimator, which consists of a 'honeycomb' of parallel tubes, is to linearize the output. To avoid errors from variations in the light-output of the lamps, or from environmental effects, a comparator method of measurement is used. Part of the light passes through the system without being interrupted by the tape, and the output from the photocells receiving this light is used as a standard for comparison with the output of the measuring photocells.

Fig. 3.4 Arrangement of bin-contents sensing system. (Transparent guide screens for tape not shown)



. . . to TEMPERATURE

Pulsing relay for multi-step control

Where electrical heating elements are used for multi-step temperature control, it may be more economical to produce the lower of two possible power inputs by pulsing the full power-rate, rather than use different heating elements. The Electrical Thermometer Co. has recently produced a pulsing relay to operate such a system. It was designed to control the heating elements in an installation by D.I.V.A. Electrical Systems for preventing icing of roads.

The installation is operated from contact thermometers, one embedded in the road and set to break contact just above freezing point, the other being in the atmosphere above the road and having its set-point slightly higher. When both thermometer-contacts are open, pulsing power is supplied to the heaters. If the temperature falls further, an overriding bimetallic thermostat holds the heater supply contactor in, to give full power until the temperature rises.

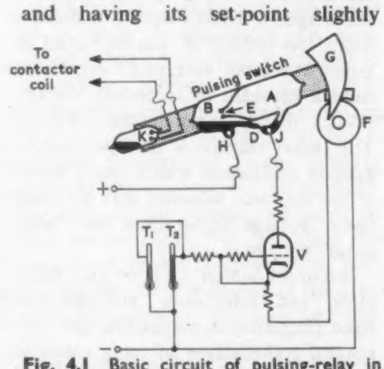


Fig. 4.1 Basic circuit of pulsing-relay in road temperature control scheme

The operating sequence can be seen from Fig. 4.1. If either of the thermometers T_1 and T_2 is making contact, a negative bias is applied to the grid of the valve V, keeping it 'cut off'. When both thermometer contacts are broken the valve conducts, the circuit being completed through the pulsing-

switch contacts and relay coil F. Armature G is then attracted by the m.m.f. of the relay coil, rotating the switch assembly through 45° in a clockwise direction, and making the contacts in the second mercury switch K. The switch controls the power supply to the heaters. The new position is held for approximately 5s while mercury drains through the constriction D into the chamber A, eventually breaking contact between H and J. The assembly then returns to the position shown in Fig. 4.1 for a further period, during which time the mercury drains back into B through a second restriction E. During this period, power to the heaters is cut off. Contact is then remade between H and J, and the cycle repeats until either the temperature rises and contact is made at T_1 or T_2, or the temperature falls further and the overriding bi-metallic thermostat by-passes the pulsing relay.

A point of interest is the design of the armature G which is pulled across the end of the coil F, gradually increasing the iron in the magnetic circuit of the coil. This makes a larger angle of tilt practicable than is obtained with a conventional relay, and is claimed to ensure more reliable action of the switch.

. . . to POSITION

Simple optical motion sensor

The principle of total internal reflection at the surfaces of a prism has been used in a new sensitive optical device made by H.H. Controls Co., for measuring small movements. The device accepts mechanical inputs and gives an output on an electrical indicator.

Fig. 5.1 shows the principle of the sensor. The motion to be measured is mechanically connected to the small (¼in square) mirror M, producing rotation of the mirror about the axis X. A parallel beam of modulated light is directed at M, and reflected on to the base of the prism P. The base angles of P are approximately 42°, which is the critical angle of the material of the prism, so that when the beam falls normally on the base, almost all of the light is totally internally reflected at the slant faces. Any movement of M causes a high proportion of the light incident on one of the slant faces to be refracted, and

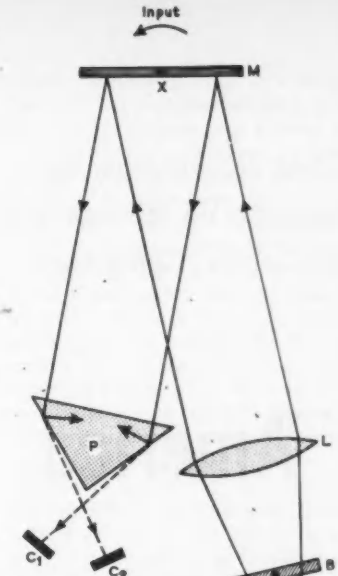


Fig. 5.1 Principle of optical sensor. In the actual arrangement the light-beam incident on the mirror M (in the null position) is vertically below the reflected beam, both beams being slightly inclined to the vertical

to fall on one of the photocells, C_1 and C_2. As the light is modulated, the resulting unbalance in the photocell signals may be used to produce an alternating output. This is amplified and demodulated to produce a d.c. signal, which is said to be proportional to the deflexion of M from the null position.

Modulated light is produced by supplying the tungsten lamp from a half-wave rectified, unsmoothed supply at mains frequency. The light is focused into a parallel beam by the lens L, and the two glass plates A and B can be rotated about axes perpendicular to the plane of the diagram to provide zero adjustment.

. . . to FLOW

Remotely controlled valve with 'non-concussive' action

A new 'on-off' valve introduced by Perrett Control Co., intended for either pneumatic or hydraulic remote operation, incorporates a compact shock-absorbing system to prevent 'hammer' in the lines.

The valve is shown in section in Fig. 6.1. The pneumatic or hydraulic operating-signal is fed to the chamber B, on the underside of the piston D, which is attached to the valve-stem. Above the piston is a further chamber A, which is connected to the upstream line pressure *via* the restriction C and a central drilling in the valve-stem. In the closed position, the valve is held on its seat by the forces exerted by the fluid in A, and by the relatively light spring E. As the cross-sectional area of the piston is greater than that of the part of the valve-disk in contact with the upstream fluid, changes in the upstream pressure will not cause the disk to lift.

When pressure is applied to the underside of the piston to open the valve, the rate of opening is controlled mainly by the resistance offered to fluid flow by the restriction C. Similarly, when the control pressure is released, rate of closing is controlled by the restriction.

Although the principle of using the line fluid to damp the action of a two-position valve has been used previously, the particular advantage claimed for this design is that the velocity of the valve stem decreases as the closed position is approached. This results from the increase in upstream pressure which occurs on closing, and the time lag in communicating this increased pressure through C to A. A further advantage claimed for the design is that

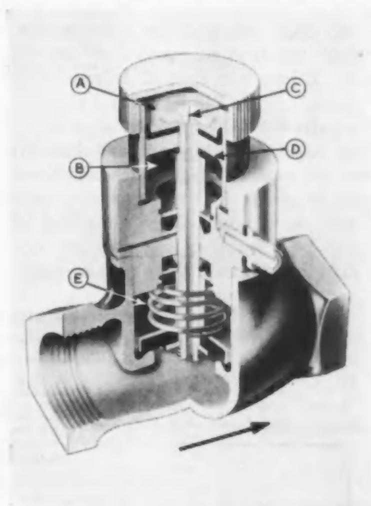


Fig. 6.1 Two-position valve with 'non-concussive' action

only moderate pressures are required for operation; the force to be overcome by the control pressure is only that exerted by the upstream line pressure operating on the difference in area between the piston and the exposed portion of the disk. Operating pressures quoted are 40–100 lbf/in², the valve being suitable for line pressures up to 125 lbf/in².

Further reports from our
American correspondents on the recent
Joint Automatic Control Conference

Look at America

Adaptive control

Several J.A.C.C. papers dealt with the design of adaptive control systems. Although there are many different meanings of the term, a definition of an adaptive control system which is applicable to most discussions of the subject is: 'A system which is capable of measuring its own characteristics, and can then change them continuously so as to maintain a certain predetermined criterion of performance'. Many schemes have been proposed for this purpose; three which were presented at the J.A.C.C. are summarized below.

Transfer-function tracking

The paper by Weygandt and Puri (*1*) presents a system which allows continuous determinations of the parameters of a linear plant, provided the numerator of its transfer function is a constant. The values thus determined are used to change the parameters of the *controller* to obtain a desired overall system response. A particular configuration is shown in Fig. 1. The plant is represented by

$$H = 1/(s^2 + as + b)$$

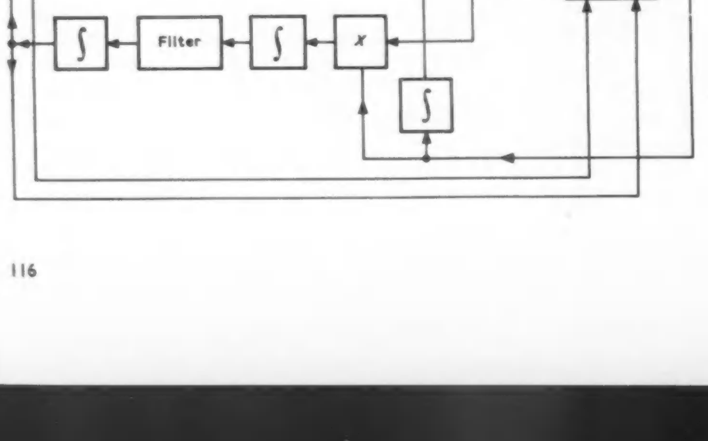
where a and b may change slowly with time in a random fashion. The controller is represented by

$$B = (s^2 + \alpha s + \beta)/(s^2 + cs + d)$$

It can be seen that the enclosed part of the diagram (Fig. 1) represents an ordinary feedback control system (except that a and b are not constant coefficients).

THIS MONTH
Adaptive control systems
New performance index

Fig. 1 Adaptive control scheme employing transfer-function tracking



All the other operations indicated make up the adaptive part of the system, the purpose of which is to cause α and β to be equal to a and b. This process is called tracking. Notice that if $\alpha = a$ and $\beta = b$, the system is entirely characterized by the denominator of the controller, hence this becomes the performance criterion toward which the system is always 'adapting' itself.

To effect the tracking, a perturbing sinusoidal signal is injected at P. The plant input is then operated on by $1/s^2$ and the plant output by $(s^2 + \alpha s + \beta)/s^2$; these are then summed to obtain the quantity Z. It is shown that Z contains information about the deviation of a from α and b from β. This information is obtained explicitly by the integrating and filtering networks, and is then used to adjust the controller parameters (and also the parameters in the $1/H'$ block). Important limitations of this scheme are: (a) the plant transfer function must have a constant for its numerator; (b) the perturbance must have significant amplitude and have a frequency lying in the band pass of the control system; (c) since α and β equal a and b respectively only in the steady state, the values of a and b must change slowly compared to the plant response.

Parameter perturbation

A somewhat similar arrangement to the one just discussed is presented by McGrath, Rajaraman, and Rideout (*2*). Fig. 2 depicts their system in its most basic form. Here the performance criterion is specified by a 'model' which operates on the input signal. The adaptive loop varies a parameter or parameters in the plant so as to make the plant output correspond closely to the model output. The difference between the two outputs becomes a new kind of system-error which the overall loop tends to

bring to zero. As before, an oscillator is used to provide a perturbation, but notice that it is a parameter which is affected, whereas in the previous arrangement, a signal was the perturbed quantity. Many variations of the basic configuration are possible, including the addition of an adaptive loop for each parameter brought under control.

An attendant mathematical analysis is used to show that information concerning the 'nearness' of the actual plant to the model is contained in the error signal, and that to obtain this information explicitly, time-averaging and filtering computations must be performed. Important restrictions on this scheme are: (a) the perturbation frequency must be much higher than input frequencies; (b) the system parameters must vary slowly compared to input frequencies; (c) for parameter-perturbation schemes similar to Fig. 2, the perturbation frequency appears in the system output.

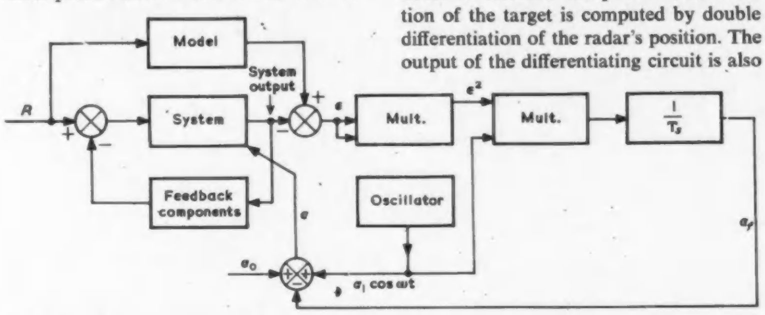


Fig. 2 Parameter-perturbation adaptive control scheme

Adaptive control of tracking radar

Application of an adaptive control system to a specific problem is described by Talkin (*3*). The problem deals with the optimum control of a tracking radar, whose characteristic equation is of second order. Such a system can be completely specified by two independent parameters, denoted by j and k. These parameters, of course, are explicitly related to the roots of the characteristic equation and also to the natural frequency and damping ratio. The problem is to specify j and k to ensure 'adequate' tracking. To allow a quantitative evaluation of the term 'adequate', a target trajectory must be assumed. In this case a fairly regular flight path is supposed, but the radar is required to follow an evasive manoeuver consisting of a 90° turn. Hence high accuracy and relatively low band-widths are required most of the time, while the system must be capable of following evasive manoeuvers (which require higher band-width) well enough to keep the radar from losing the target. The author points out (as have others in the past) that when optimization by minimizing the integral of squared error is attempted, the system is too under-damped in the presence of transients, e.g. a sharp turn executed by the target. Hence, a critically damped response is chosen as a compromise. The other parameter left, then, is the natural frequency. This should be as low as possible, consistent with target trajectory, for noise filtering purposes.

The scheme finally used computes two quantities, the sum of which directly manipulates the system's natural frequency. First, the error signal is averaged over time by a filter. As the value of the averaged error increases, the band-width of the system is increased by the adaptive components. This method works well for the smooth part of the target trajectory but is unable to cope with sharp changes, mainly caused by the relatively large amount of averaging time required by the filter. To alleviate this problem, acceleration of the target is computed by double differentiation of the radar's position. The output of the differentiating circuit is also used to regulate the natural frequency, and the system is then able to track adequately under both situations.

The use of adaptive techniques allows the radar to perform satisfactorily when the signal-to-noise ratio is 10dB. A corresponding linear system requires a signal-to-noise ratio of 13dB for satisfactory performance, implying a 30% improvement gained by the use of adaptive techniques.

New performance index for linear systems

In the past many different performance indices have been proposed for use in optimizing linear control systems*. Of these the ISE (integral of error-squared) index has been widely discussed and frequently used:

$$I = \int_0^\infty e^2(t)\mathrm{d}t$$

Minimization of this quantity for a given system will give 'optimum' performance for random inputs. Unfortunately, it also will tend to yield highly underdamped systems when transient inputs are present. The ISE and other similar error-integral indices suffer from the drawback that their use does not provide any *a priori* knowledge of what the optimized system response will be. It would be much more desirable if, at the outset, the designer knew what kind of response to expect from an optimized system, or even better still, if he were able to choose at the outset what the characteristics of the optimized system should be.

An index proposed by Rekasius (*4*) allows the selection of an ideal transient response which could be achieved if enough of the parameters in the actual system were adjustable. The absolute minimum value of this performance index, $I_{min\ min}$, corresponds to this ideal response, expressed by a homogeneous linear differential equation. In a real situation where only some of the system parameters are accessible, a minimum value, I_{min}, can be found by suitably adjusting them. The parameters that yield I_{min} then represent the optimum system, and the smaller the difference between I_{min} and $I_{min\ min}$, the closer will be the optimized system performance to the specified ideal response. Hence this technique allows the preselection of the desired response, and provides an analytical method for bringing the actual system response as close to it as possible.

The index, I, which provides the above features is defined as

$$\int_0^\infty \left[x^2 + \sum_{i=1}^{k} \tau_i^2\left(\frac{\mathrm{d}^i x}{\mathrm{d}t^i}\right)^2 + 2x \sum_{i=2}^{k} \tau_i \frac{\mathrm{d}^i x}{\mathrm{d}t^i} + 2\sum_{i=1}^{k}\sum_{j=i+2}^{k} \tau_i\tau_j \frac{\mathrm{d}^i x}{\mathrm{d}t^i}\frac{\mathrm{d}^j x}{\mathrm{d}t^j}\right] \mathrm{d}t, k < n \tag{1}$$

where n is the order of the actual system, k is the order of the ideal model, and $x(t)$ is the error, defined in Fig. 3 by

$$x(t) = C_{ss} - C(t)$$

The τ_i's ($i = 1, 2, \ldots k$) are constants obtained from the differential equation of the ideal system. Expanding the quadratic term in Eq. 1 gives

$$I_k = \int_0^\infty \left[x + \sum_{i=1}^{k} \tau_i \frac{\mathrm{d}^i x}{\mathrm{d}t^i}\right]^2 \mathrm{d}t - 2\int_0^\infty \left[\tau_1 x \frac{\mathrm{d}x}{\mathrm{d}t} + \sum_{i=1}^{k-1} \tau_i\tau_{i+1} \frac{\mathrm{d}^i x}{\mathrm{d}t^i}\frac{\mathrm{d}^{i+1}x}{\mathrm{d}t^{i+1}}\right]\mathrm{d}t, \quad k < n \tag{2}$$

If the system is stable and the steady-state error is zero, i.e.

$$x(\infty) = \frac{\mathrm{d}x(\infty)}{\mathrm{d}t} = \ldots \frac{\mathrm{d}^k x(\infty)}{\mathrm{d}t^k} = 0$$

then Eq. 2 can be written

$$I_k = \int_0^\infty \left[x + \sum_{i=1}^{k} \tau_i \frac{\mathrm{d}^i x}{\mathrm{d}t^i}\right]^2 \mathrm{d}t + \tau_1 x^2(0) + \sum_{i=1}^{k-1} \tau_i\tau_{i+1}\left[\frac{\mathrm{d}^i x(0)}{\mathrm{d}t^i}\right]^2, \ k < n \tag{3}$$

Now the absolute minimum, $I_{min\ min}$, for Eq. 3 occurs when the integrand is equal to

* See *Control* Sept. 1961, pp. 115–116

zero. This is equivalent to stating that $I_{min\ min}$ exists when

$$x + \tau_1 \frac{dx}{dt} + \ldots + \tau_k \frac{d^k x}{dt^k} = 0, k < n \tag{4}$$

Hence, Eq. 4 represents the ideal model for the performance index defined by Eq. 1. Eq. 4, of course, corresponds to a closed-loop transfer-function represented by

$$C(s)/R(s) = 1/(\tau_k s^k + \tau_{k-1} s^{k-1} + \ldots + \tau_1 s + 1) \tag{5}$$

To illustrate the implications of the foregoing, consider that the desired ideal transient response of a system is specified by

$$C(t) = C_{ss} - \sum_{i=1}^{k} A_i e^{-t/T_i}$$

or, from the definition of $x(t)$

$$x(t) = \sum_{i=1}^{k} A_i e^{-t/T_i} \tag{6}$$

Substitution of Eq. 6 into Eq. 4 gives the constants τ_i of the ideal model. Next it is necessary to find the particular performance index I_k as defined by Eq. 1. To do this let

$$I_k = \lim_{t\to\infty} \int_0^t W\left(x, \frac{dx}{dt}, \ldots \frac{d^k x}{dt^k}\right) dt$$

$$= \lim_{t\to\infty} [V(t) - V(0)] \tag{7}$$

$V(t)$ is evaluated by assuming it to be of the form

$$V = a_{11}x^2 + \sum_{j=2}^{n} a_{1j} x \frac{d^{j-1}x}{dt^{j-1}}$$

$$+ \sum_{i=2}^{n} \sum_{j \geqslant i}^{n} a_{ij} \frac{d^{i-1}x}{dt^{i-1}} \frac{d^{j-1}x}{dt^{j-1}} \tag{8}$$

From Eq. 7 it is seen that

$$W = \frac{dV}{dt}$$

Since the systems under consideration are considered to be stable, the error and all its derivatives become zero as $t \to \infty$. If this is true, then

$$\lim_{t\to\infty} V(t) = 0 \text{ (from Eq. 7)} \tag{7a}$$

Hence, from Eq. 7,

$$I_k = -V(0) \tag{9}$$

Thus to calculate the numerical value of I_k, substitute the initial values of x and its time derivatives into the expression for the V function, Eq. 8. This will yield an expression for I_k which is a function of the system parameters. The parameters are then adjusted so that $I_{k\ min}$ is obtained. Then the physical system utilizing these parameters is as close as it can be to exhibiting the ideal response.

As a specific example, consider the system of Fig. 3, and let $G(s) = k/[s(1 + s)^2]$, and $H(s) = 1$. It is desired that the ideal response be specified as

$$\frac{d^2x}{dt^2} + 2\frac{dx}{dt} + x = 0 \tag{10}$$

Find the value of k that will allow the closest approximation of the actual system to

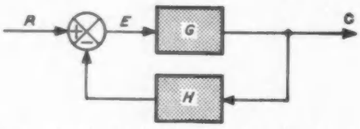


Fig. 3 Linear feedback control system

Eq. 10. Comparing the above equation with Eq. 4 gives $\tau_2 = 1$, $\tau_1 = 2$. Then, from Eq. 1

$$I_2 = \int_0^\infty \left[x^2 + \tau_1^2\left(\frac{dx}{dt}\right)^2 + \tau_2^2\left(\frac{d^2x}{dt^2}\right)^2\right.$$

$$\left. + 2x\tau_2\left(\frac{d^2x}{dt^2}\right)\right] dt = \int_0^\infty \left[x^2 + 4\left(\frac{dx}{dt}\right)^2\right.$$

$$\left. + \left(\frac{d^2x}{dt^2}\right)^2 + 2x\left(\frac{d^2x}{dt^2}\right)\right] dt \tag{11}$$

Since the given physical system is 3rd order ($n = 3$), the V function, Eq. 8, becomes

$$V = a_{11}x^2 + a_{12}x\left(\frac{dx}{dt}\right) + a_{13}x\left(\frac{d^2x}{dt^2}\right)$$

$$+ a_{22}\left(\frac{dx}{dt}\right)^2 + a_{23}\left(\frac{dx}{dt}\right)\left(\frac{d^2x}{dt^2}\right) + a_{33}\left(\frac{d^2x}{dt^2}\right)^2 \tag{12}$$

$$\text{Also} \quad W = \frac{dV}{dt} = 2a_{11}x\left(\frac{dx}{dt}\right) + a_{12}x\left(\frac{d^2x}{dt^2}\right)$$

$$+ a_{12}\left(\frac{dx}{dt}\right)^2 + a_{13}x\left(\frac{d^3x}{dt^3}\right) + a_{13}\left(\frac{dx}{dt}\right)\left(\frac{d^2x}{dt^2}\right)$$

$$+ 2a_{22}\left(\frac{dx}{dt}\right)\left(\frac{d^2x}{dt^2}\right) + a_{23}\left(\frac{dx}{dt}\right)\left(\frac{d^3x}{dt^3}\right)$$

$$+ a_{23}\left(\frac{d^2x}{dt^2}\right)^2 + 2a_{33}\left(\frac{d^2x}{dt^2}\right)\left(\frac{d^3x}{dt^3}\right) \tag{13}$$

To eliminate d^3x/dt^3 from the above, note that

$$C/R = k/[s(1 + s)^2 + k]$$
$$= k/[s^3 + 2s^2 + s + k]$$

and the corresponding characteristic equation is

$$\frac{d^3x}{dt^3} + 2\frac{d^2x}{dt^2} + \frac{dx}{dt} + kx = 0$$

solving for d^3x/dt^3 and substituting into Eq. 13 gives

$$\frac{dV}{dt} = W = (-ka_{13})x^2 + (2a_{11} - a_{13}$$

$$- ka_{23})x\left(\frac{dx}{dt}\right) + (a_{12} - 2a_{13}$$

$$- 2ka_{33})x\left(\frac{d^2x}{dt^2}\right) + (a_{12} - a_{23})\left(\frac{dx}{dt}\right)^2$$

$$+ (a_{13} + 2a_{22} - 2a_{23} - 2a_{33})\left(\frac{dx}{dt}\right)\left(\frac{d^2x}{dt^2}\right)$$

$$+ (a_{23} - 4a_{33})\left(\frac{d^2x}{dt^2}\right)^2 \tag{14}$$

Comparison of Eq. 14 with Eq. 11 and Eq. 7 shows that

$$-ka_{13} = 1 \qquad a_{12} - 2a_{13} - 2ka_{33} = 2$$
$$a_{12} - a_{23} = 4 \qquad 2a_{11} - a_{13} - ka_{23} = 0$$
$$a_{23} - 4a_{33} = 1 \qquad a_{13} + 2a_{22} - 2a_{23} - 2a_{33} = 0 \tag{15}$$

Simultaneously solving these yields

$$a_{11} = \tfrac{1}{2}(k^3 + 4k^2 + 3k + 2)/(k^2 - 2k)$$
$$a_{12} = (5k^2 - 8k + 8)/(k^2 - 2k)$$
$$a_{13} = -1/k = (2 - k)/(k^2 - 2k)$$
$$a_{22} = (k^2 + 6k)/k^2 - 2k)$$
$$a_{23} = (k^2 + 4k + 4)/(k^2 - 2k)$$
$$a_{33} = (1{\cdot}5k + 1)/(k^2 - 2k) \tag{16}$$

For this system, the initial conditions pertaining to a unit step are

$$x(0) = 1, \frac{dx}{dt}(0) = 0, \frac{d^2x}{dt^2}(0) = 0$$

Thus, from Eqs. 7, 7a, 8, 9 and 16

$$I_2 = -V(0) = \frac{(k^3 + 4k^2 + 3k + 2)}{-2(k^2 - 2k)} x^2(0)$$

$$= \frac{k^2 + 4k^2 + 3k + 2}{4k - 2k^2} \tag{17}$$

Now the optimum system corresponds to the minimum value of I_2. This occurs when $k = 0{\cdot}43$, and consequently $I_{2\ min} = 3{\cdot}04$. $I_{min\ min}$ is found by substituting Eq. 4 into Eq. 3 which gives $I_{min\ min} = 2{\cdot}0$. Whereas the desired response (Eq. 10) is critically damped, the best response that can be obtained by adjusting k is somewhat underdamped.

In summary, the technique proposed here assumes a given physical system with a certain number of adjustable parameters. In the example, only the open loop gain k could be varied. Then an ideal, desired response is specified by means of a differential equation (Eq. 10). The absolute minimum of the performance index, $I_{min\ min}$, is found by evaluation of Eq. 11, which is equivalent to substituting Eq. 4 into Eq. 3. To find the expression for I in terms of the physical system constants, the steps comprising Eqs. 11–17 were taken. Then the constants (in this case, just k) were adjusted to make I a minimum. The closer I approaches 2·0, the closer is the actual response to the specified response. If more than one parameter in the physical system could be varied, the minimum value for I would be less than 3·04, and a closer approximation to the specified response could be obtained.

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A chromatographic closed-loop control system

by **R. J. CARTER** B.Sc.*

THERE IS A GROWING AWARENESS OF the desirability of chromatographic control in the chemical and petroleum process industries, and commercial equipment for closed-loop chromatographic control is now becoming readily available. However, since the control system now in use is so unsophisticated, inexpensive, easily understood and maintained, it does provide an attractive means for achieving closed-loop control in a large number of applications, although its use may possibly be restricted in particularly difficult control situations. In addition, the instrument does have the advantage that it permits, if so desired, independent closed-loop control systems to be obtained for each of the possible component analyses given on a single chromatograph.

Chromatographic control

Process chromatographic analysers have several advantages: they offer direct component analysis, high sensitivity and reproducibility, and reliability of operation. However, for application in a closed-loop system there is one main disadvantage in that the indication of a key component is discontinuous, a short-duration peak value of each component reading being given once every sample-cycle. Hence the need to provide a continuous signal corresponding to the peak height for each of the key components to be controlled, each continuous signal being retained for the duration of each cycle.

The effect of the chromatographic cycle-time on control action needs careful consideration. Its action is similar to that of dead-time (distance/velocity lag). Thus the first problem is to ensure that the analysis time should not be so long as to prevent good recovery from a disturbance in a closed-loop control system. This problem was considered in the particular system at present in use, and discussed here. In this system the control of key component is direct, that is to say, the control is applied directly to the feed of key components into the process. The same consideration would apply to an indirect control such as is experienced in the maintenance of a composition specification in a distillation column through temperature control.

Generally speaking, the method of control is particularly suited to processes where the ratio d/T is not very much greater than 0·1 where d is the dead-time plus analysis cycle-time and T is the longest process time constant. For a ratio of $d/T = 0{\cdot}1$, then the maximum difference between two successive peaks is only 10% of the step change creating that difference (i.e. $1 - e^{-0\cdot1} = 1 - 0{\cdot}9048$ which is 9·52% when expressed as a percentage). This means that a 10% full-scale deflexion change in set point will result in a *maximum* difference between successive peaks of only 1% of full-scale deflexion. However, the important thing to note is that the ratio of d/T for any system must be kept small (less than 0·1) if good control is to be achieved easily and simply. This does not mean that for d/T greater than 0·1 good control is not possible, but it does mean that automatic start-up without overshoot will be improbable and a three-term control mode may be necessary. Hence it is advantageous to ensure that the analysis cycle-time is such that d/T is less than 0·1.

It is worth noting that analysis cycle-time is probably not identical in action to dead-time. Nevertheless, the above considerations do give a very good idea of the value of analysis cycle-time required to ensure good recovery from a disturbance in a closed-loop system.

One further use of the ratio d/T is that it does give some idea of the narrowest usable proportional band width, particularly if the process transfer function is a first-order lag with time constant T. Again, bearing in mind that analysis cycle-time may not be identified directly with dead-time, a rough value of the narrowest proportional band will be about $100d/T$%.

The actual process transfer function of the system discussed here was in fact a first-order lag with a time constant of about six hours. Unfortunately, in addition to this lag there was a dead-time of about fifteen minutes which could not be reduced by relocation of the control valve or other equipment. The analysis cycle-time in use was five minutes. Hence d/T was given as $20/360 = 0{\cdot}055$. This meant that automatic start-up without excessive overshoot seemed possible and the narrowest usable proportional band would be about 6%. In practice it was found that automatic start-up was satisfactory but a proportional band of 6% was too near to the critical value to give adequate

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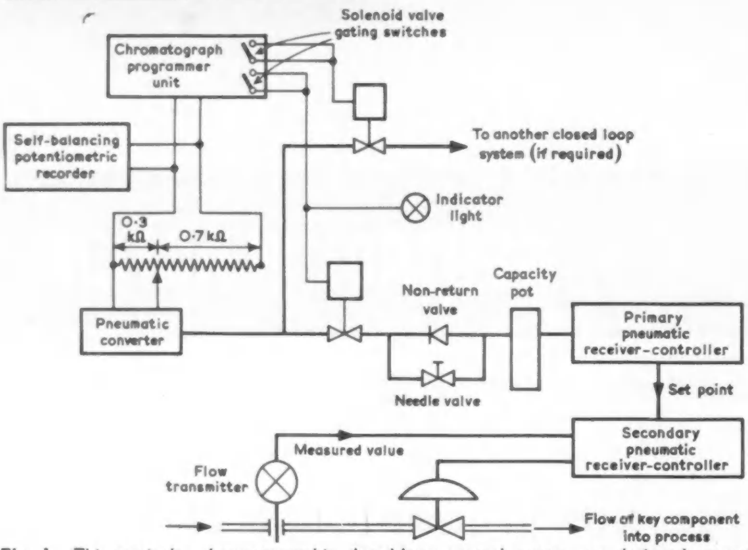


Fig. 1 This particular chromatographic closed-loop control system was designed around such hardware as was readily available

settling time. A proportional band of 10–15% gave excellent control to better than ±0·25% of full-scale deflexion, but some off-set had to be tolerated. Reset action could not be applied as the desired integral action time was several hours and the controllers available at the time were not capable of giving this.

In this particular system the existing sample cycle-time was already of a suitable value. It is worth noting, however, that commercial equipment already installed could, perhaps, have been modified for high-speed chromatography. Nevertheless, before considering modification it is worth investigating the cycle-times possible with the aid of a short silica-gel column (treated with a suitable wetting agent). With the equipment actually used it would have been possible to reduce the analysis cycle-time to less than two minutes with a column change and the fitting of a faster cycle-timer motor only, and still retain adequate sensitivity for the component in question.

Basic mode of operation

The schematic diagram illustrates the actual control system installed. There are many possible variations to the actual hook-up used, and better arrangements are possible. However, this particular hook-up was simply a result of the hardware readily available. The basic requirements are as follows.

Equivalent pneumatic output

Most, if not all, chromatographic analysers give an electrical output and hence to obtain an equivalent pneumatic output some form of electro-pneumatic converter is required. In this particular system, the output was presented on a self-balancing potentiometer which contained the limit switches necessary for chromatograph zero-balancing. This potentiometer was retained and fed in parallel with a separate converter. However, there is no reason why the self-balancing potentiometer should not in itself contain a simple pneumatic converter unit. One interesting point arose from the need to use a 1kΩ potentiometer. This resulted from the fact that the source impedance presented to the converter was too high to give adequate speed of response from the converter. The potentiometer was adjusted so that the value across the converter was 300 ohms and its mV/(lbf/in^2) sensitivity adjusted accordingly.

Peak peaking of the pneumatic equivalent output

This was achieved by a combination of solenoid-valve gating, a low (virtually zero) differential non-return valve and needle bleed valve. The solenoid valve was gated so that it opened about 3% of cycle-time before the ultimate peak value, and closed about 0·3% of cycle-time after the ultimate peak value. In the 3% of cycle-time before peak value, the bleed around the non-return valve allowed the previous continuous peak value to fall by a few per cent, whilst the 0·3% of cycle-time after the peak value prevents significant bleed-off of the newly established signal. In any case, the small amount bled-off in this time does not affect the accuracy of the system because it is a constant for any desired control peak value. Hence, a continuous signal, corresponding to peak height, apart from very short-duration pulses, is fed to the appropriate pneumatic controller.

Some important practical details need to be emphasized. These are:

RATE OF BLEED. For a ratio of d/T less than 0·1 it is seen that the very worst percentage difference needed is 10%, and that this is given only for a downward change of set point to zero value. For such a 'shut-down' requirement the manual position of the pneumatic controller would be used. Hence, since the bleed is not required on start-up with rising peak values a bleed of 3% for $d/T = 0{\cdot}1$ should be ample in practice. However, the system is capable of giving bleed-off of peak values of up to 20% with adequate retention of the following peak value. Hence it can be used with d/T values of much greater than 0·1. Because of this it will probably embrace all possible control situations, but there is insufficient evidence to state this with great certainty.

EFFECT OF BLEED PULSE. The effect of pulses is negligible. This is best illustrated by considering the effect for a 3% cycle-time bleed in a system with a 10% bleed and d/T of 0·1.

A ramp pulse form will be given (assuming ideal secondary controller response) of about $(3/100) \times (10/200)$ cycle-times peak value in the process.

The process capacity measured in the same peculiar units is of the order of 1/0·1.

Hence the effect of ramp pulse is of the order of $(3/100) \times (10/200) \times (0{\cdot}1/1) \times (100\%) = 0{\cdot}015\%$.

SOLENOID VALVE GATING. This was very easy to achieve since the cycle-time shaft of the particular chromatograph used had a built-in facility for cam-actuated mercury switching. The cam was shaped to actuate the mercury switch for the suitable duration time and positioned on the shaft to cut out the required 0·3% of cycle-time after the peak. The 0·3% figure quoted is only a rough idea of what is necessary, but it is dangerous to reduce this time to below 0·1%, say, because of possible small elution time drifts. This is the reason for fitting the indicator light shown in the diagram (Fig. 1) because it is essential to know that the solenoid valve does not close before the peak value has been reached.

If it is not possible to use the cam and mercury switch system it is suggested that a micro-switch is used on the timer-system of the chromatograph. This can then be used to actuate a delay relay.

NON-RETURN VALVE. This was a particularly interesting practical aspect.

Although very low differential non-return valves are available commercially, an inexpensive and quite conventional bronze Y-type check valve was used. By machining down the flapper-type plug and fitting an O-ring on it, a 100% seal-off was easily achieved. Even with the valve mounted vertically the differential was effectively zero. However, by mounting the check valve so that the weight of the flapper-plug justs holds it on its seat, zero differential is theoretically possible.

CAPACITY POT. This was a normal filter container of about 30in^3 capacity. With this capacity the pneumatic signal had no difficulty in following the chromatograph peak value, but it must be remembered that the capacity used for 'leak insurance' purposes must be in proportion to the cycle-time value.

Benefits of the installed system

Before the system was installed the process operators had a very irksome task in manually controlling the peak component value. The value of key component was not always kept within the desired control limits and the product quality control suffered occasionally. In addition, small changes in the value of key component were difficult to make when a quality control correction was needed.

One result of the closed-loop control system, quite apart from relieving the process operators of an irksome task, is an improvement in quality control which has already repaid the cost of development and installation. Quality control corrections are now made quickly and positively by a simple set-point change, and start-up values are also achieved quickly without demanding close attention to the equipment, and so giving faster on-grade start-up conditions.

The system has now been on-stream for over a year and is well proved. Because of its advantages it is to be installed in similar process units in the plant.

Programming rolling mills automatically

PUNCHED CARDS ARE USED TO STORE rolling programs for steel rolling mills in a new automatic programming system developed by English Electric's Metal Industries Division. These programs consist of the complete rolling sequence, covering screwdown, manipulator, mill-speed, and the number of passes through the mill. The system is now in operation at the Hallside reversing billet mill of Colvilles Ltd, where it is controlling the screwdown.

The system consists of three units, a card store (Fig. 1), a card punch (Fig. 2) and a card reader (Fig. 3). Briefly, a plastics card is punched with the required pattern of holes and fed into a card reader. There, photo-transistors sense light passing through the punched holes, and the resulting signals are fed to the control scheme in accordance with the hole configuration in the card.

The plastics cards, which are $\frac{1}{32}$in thick and claimed to be practically indestructible, are supplied with drive holes and two card-entry sensing holes already punched, and are stored in a case (Fig. 1) capable of holding up to 100 cards.

Card punching

It is likely that most users will wish to punch the program cards themselves, and to do this immediately after the successful proving under manual control of a particular rolling program. English Electric will, however, supply cards ready-punched to the user's specification if required.

The card punch (Fig. 2) consists of a hydraulic thrust unit and a press, the latter having a keyboard with keys arranged in the same manner as the punched holes in a completed card. Depressing a key moves a steel slug over the desired punch and, once depressed, all keys remain down to facilitate checking before punching.

The card is located on pegs on the press table, and on operating the 'punch' button the hydraulic unit drives a die block to punch the holes selected on the keyboard. When the die block reaches the top of its travel, a limit switch operates, causing the die block to retract and the card to move forward one position in readiness for a further group of holes to be selected by the keyboard.

Card reading

Fig. 3 shows the card reader in use at Colvilles—the operator is inserting a program card into the reader. All the information necessary for one pass of the mill may be stored on a double line on the card, which is advanced section by section for each pass. There is, therefore, no need for an intermediate memory store, since the information for a particular pass remains under the reader for as long as required. A double, rather than a single, line is used as it permits a staggered formation of scanning cells and so a card and reader of reasonably narrow dimensions.

The photo-transistors are stimulated by light from a strip-lamp unit, in a manner depending upon the configuration of holes in the card, and their outputs are fed to transistor amplifiers and then used to control small plug-in relays. The relays can operate any of the three position-control systems em-

Fig. 1 Removing a program card from the store. A card reader is in the foreground

Fig. 2 Punching a rolling-mill program into a plastics car

Fig. 3 Screwdown control system at Colvilles' Hallside reversing billet mill. The operator is inserting a program card into the reader

ployed by English Electric, potentiometer analogue—as at Colvilles, synchro analogue, or digital.

The manufacturers claim that the prototype programmer has performed over 6,000,000 operations without failure, but have still felt it necessary to incorporate a parity check circuit which monitors every pass. This circuit requires that an odd number of relays should be energized on each pass, otherwise the output is cancelled and a warning lamp lights. This parity check will detect a fault in the light source, photo-transistors, amplifier transistors, relays, or power supplies. The use of a test card will detect a faulty channel.

Operation

To program-control a rolling mill, the particular card is placed in the reader, as in Fig. 3, correct orientation of the card causing it to be driven to the first sensing position. The card is then advanced through the reader by operating a push-button. A reset button may be used to recall the card to the first sensing position, but normally the card will be reset automatically on completion of the program, to be used again or rejected.

According to English Electric, the pass progression can be made completely automatic by feeding back control signals from the mill after each pass.

Control at Drakelow 'B'

Another C.E.G.B. power station opened

THE C.E.G.B.'S 746-ACRE DRAKELOW site, near Burton-upon-Trent, will eventually hold three power stations: 'A' which consists of four 60MW turbo-generator sets, 'B' consisting of four 120MW sets, and 'C' which will have two 350MW sets and two 375MW sets. The fourth unit of the 'A' station was commissioned in November 1955, and the four units (Nos 5 to 8) of Drakelow 'B' were all in operation by the end of 1960. Drakelow 'B', which was visited by *Control* recently, was officially opened on 20 October.

The 'B' station's four 120MW turbo-alternators, one of which (No. 5 unit) is out of service at the moment, are all by C. A. Parsons, but the steam-raising plant was provided by two different contractors, No. 5 boiler being by International Combustion and Nos 6, 7 and 8 boilers by Foster Wheeler. All are fired by pulverized fuel and are single-drum reheat boilers, with an evaporative capacity of 860,000 lb/h.

Boiler control

The automatic boiler control system is by Electroflo Meters Co. Ltd, who were responsible for the majority of the instrumentation and controls at Drakelow 'B'. The boiler system provides constant control of steam pressure, combustion rate and combustion chamber pressure. The steam conditions at the superheater outlet are 1600 lbf/in² and 1010°F, reheating from 697°F to 1005°F at 367 lbf/in² between the high-pressure and intermediate-pressure cylinders of the turbine.

The rates of fuel- and air-flow are controlled in a predetermined ratio, with automatic correction for changes in fuel quality by the continuous comparison of steam evaporation with the amount of combustion air used (it is accepted that the air flow for correct combustion is proportional to steam flow).

The Electroflo installation combines a pneumatic system with hydraulic and pneumatic cylinders which perform particular actuation duties, the various controllers being of the force-balance type.

Steam pressure

A master controller which is connected to the steam mains, maintains steam pressure at the desired level. This controller converts the changes in steam pressure which occur with variations in steam load, into pneumatic signals which are transmitted to the individual regulators controlling combustion rate.

An air-flow controller regulates combustion air, the inlet vanes of the two constant-speed forced-draught fans being positioned in parallel by two regulators which are fed from a sender relay in the controller. The air-flow differential is measured in each of the f.d. fan inlet ducts by Venturi contractions feeding pneumatic transmitters, the resulting signals being

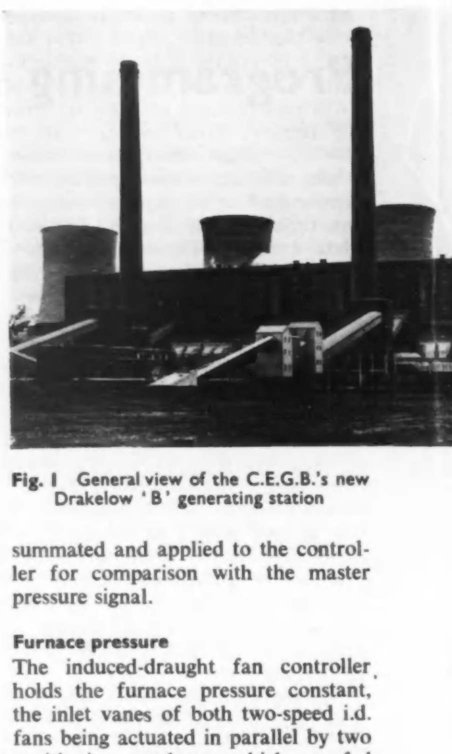


Fig. 1 General view of the C.E.G.B.'s new Drakelow 'B' generating station

summated and applied to the controller for comparison with the master pressure signal.

Furnace pressure

The induced-draught fan controller holds the furnace pressure constant, the inlet vanes of both two-speed i.d. fans being actuated in parallel by two positioning regulators which are fed from a sender relay in the controller. The latter senses combustion chamber pressure and is independent of the master controller. The pressure control setting can be altered remotely from the control panel in order to suit such unusual conditions as could occur during, say, soot-blowing.

Fuel feed

No. 5 boiler has five suction-type roller mills, one being for standby duties, and Nos 6, 7 and 8 boilers each have three double-ended ball mills.

On No. 5 unit the master signal controls the speed of the feeder motors, and also the mill exhauster fans, the

control signal to the latter being biased by the primary air requirements of the mills.

On the three Foster Wheeler boilers, Nos 6, 7 and 8, the master control signal is fed into a sender regulator and modified by the differential across the classifier. This modified signal is fed to regulate positioning actuators on the output dampers of the mills.

Steam temperature

There are in effect two groups of steam-temperature control equipment, one for main steam temperature, and the other for the reheat steam temperature. On No. 5 boiler (International Combustion) steam temperature control is by George Kent equipment, two Multelec potentiometric recorder-controllers providing control signals (*via* an auto/manual control valve) to a diaphragm-operated spray-water control valve. This in turn regulates the quantity of spray water injected into the steam for desuperheating purposes.

Reheat steam temperature is regulated by tilting the burners. Steam temperature is measured by a recorder-controller by means of a thermocouple in the reheater steam outlet, and the resulting pneumatic signal operates power cylinders coupled to the moveable fuel-firing burners. In addition, the temperatures at the superheater and reheater outlets can be varied manually using gas by-pass dampers and gas recirculation fans.

On Nos 6, 7 and 8 boilers (Foster Wheeler) temperature control is entirely by Electroflo. Main steam temperature control is effected by characterizing the master control signal in accordance with the expected steam-load/steam-temperature relationship, and correcting this signal for any temperature deviation. Diaphragm valves control the water feed to attemporators. Steam temperature at the reheater outlets is automatically controlled by regulation of by-pass dampers in relation to reheat temperature measurement. In an emergency, spray desuperheaters in the reheater inlet pipework can also be used.

Feed water

The feed water to the boilers is heated to 435°F (at the economizer inlet) by steam bled from the turbines. The flow of feed water is controlled by two valves actuated by positioning regulators to maintain a constant level of water in the steam drum. These regulators operate on a signal from a sender which receives pneumatic signals from steam-flow, feed-flow and drum-level transmitters. These signals are compared in such a manner that feed-flow requirements are anticipated by changes in steam flow, and constant drum-level is thus maintained.

Plant control rooms

Two control blocks are arranged between the turbine room and the boiler house, and in each of these is an air-conditioned room with double-glazing and sound-insulation, which houses the Electroflo control panels, desks and recorder panels for two units. Fig. 2 shows the control room for Nos. 5 and 6 units.

All instruments for automatic control of two boilers, coal-pulverizing plant, and the two turbines, are located in each control room, together with the remote controls for auxiliary motors, turbine supervisory equipment and alarm systems. (The latter were provided by Standard Telephones and Cables.) Telemetering, both electrical and pneumatic, is used extensively so that there is no need for high-pressure high-temperature steam, and water to enter the control rooms.

Auto/manual sub-panels on the unit control desks, permit the operator to switch the boiler from automatic steam-pressure control to unified manual control or, alternatively, to individual operation of all regulators.

Television equipment for monitoring the drum levels for all boiler plant is by Hopkinsons Ltd. Combustion-chamber monitoring on No. 5 boiler is by Pye television equipment, and on Nos 6, 7 and 8 by Rank Cintel. It is understood that the C.E.G.B. have high hopes of combustion-chamber monitoring by television, but that their success at Drakelow 'B' so far has been marginal only.

Electrical and ancillary controls

A single electrical control room caters for the generating systems for both the 'A' and 'B' stations at Drakelow. Here there are situated such ancillary controls as water-pump-motor control desks, automatic voltage regulators and the chlorination programmer.

The four 120MW Parsons' sets have main speed governors which control the high-pressure steam-admission valves, an independent auxiliary governor regulating the intercepting and unloading valves. The auxiliary governor can thus be set independently of the main governor.

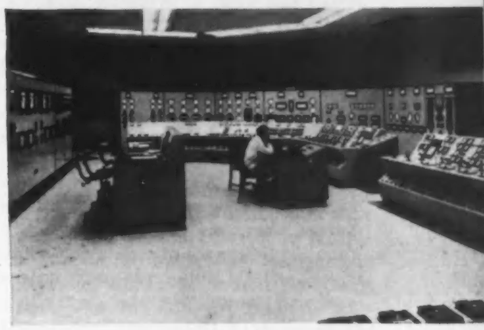


Fig. 2 The control room for Nos. 5 and 6 units

The automatic voltage regulator is of the quick-response static type incorporating a magnetic amplifier and a twin amplidyne set. A follow-up mechanism permits smooth change-over from automatic to manual control. Each turbo-generator is fitted with supervisory equipment to indicate and record speed, output, eccentricity, differential expansion and vibration.

The chlorination plant (Wallace and Tiernan Ltd) is also of some control engineering interest as it is controlled by an electric program clock within the Station Control Room. The chlorinators installed for the 'A' station are used, each chlorinator having a maximum capacity of 250 lb/h of chlorine, with automatic intermittent operation under program control.

Ferranti's automatic drill

Drilling printed-circuit boards automatically

THE LARGE NUMBER OF PRINTED-CIRCUIT boards employed in a modern digital computer, has led Ferranti Ltd to design a fully automatic 'printed circuit drill' for drilling component-fixing holes in these boards. Although designed with Ferranti's own needs in mind—it has already been successfully used for drilling the hundreds of boards required for the Atlas high-speed computer, and the Argus process control machine—it is now in limited quantity production by Ferranti, Edinburgh, and is to be marketed at £3600.

Basically, the machine consists of two drilling heads (giving either tandem or single-spindle working), a hydraulically operated co-ordinate table which carrys the printed boards and is moved automatically to bring the hole centres in turn below the

drills, and an automatic control system for the drilling action and table movement.

The 20in by 14in drilling table is moved parallel with, and at right angles to, the front of the machine by hydraulic jacks. Hole-centres are positioned under the drills in two stages: first, they are roughly positioned with the aid of a perforated template and photo-electric cells and, secondly, accurately positioned by a mechanical indexing system using the meshing of a half-nut with a precision rack. A positional accuracy of ±0·001in and repeatability to within 0·001in are claimed.

Drilling is carried out to a grid system based on a pattern of rows and columns, the spacing between rows of the grid system being determined by the pitch of the thread of the precision rack associated with row alignment. A typical pitch is 20 threads/in, giving a spacing between rows of 0·050in or multiples thereof. A similar precision rack is used for column alignment, although the basic spacing need not be the same for rows and columns.

The perforated template is mounted on an extension of the drilling table, and whenever a hole in the drilling area of the template coincides with the light beam, the photo-electric cell provides a signal to the machine's control system. This signal (a) halts the oil flow to the hydraulic jacks, so stopping the drilling table, (b) applies oil to the half-nut mechanism thus meshing the half-nut with the rack, and so locating and locking the table in position, and (c) switches power to the drills.

When the drilling action is complete, a signal is fed to the control system, releasing the half-nut from the rack, and re-starting the flow of oil to the jacks which move the table. The process is then repeated for the next hole in the template.

When a row of holes has been drilled, the table moves to bring the next row into line with the drilling heads. There are two columns of row-marker holes in the template, each row of the drilling pattern having an associated row-marker hole. These holes stimulate the photo-electric cell and the resulting signal to the control system causes the table to move up to and along the next row. When the last hole is drilled, the drilling table returns to its start position and halts.

The machine can accommodate a single stack—up to ⅜in deep—of one or more printed-circuit boards measuring up to 12½in by 18in with maximum drilling dimensions of 11½ by 17½in. Alternatively, it can accommodate two stacks of identical boards for simultaneous drilling, each board measuring up to 12½in by 8½in.

A grid system based on a pattern of rows and columns gives precision drilling

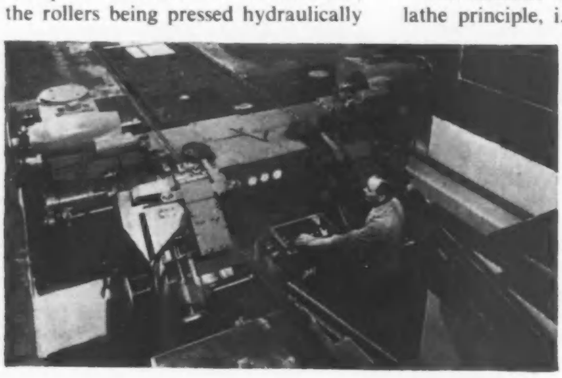
The machine's rate of output is, of course, dependent on the pattern of holes to be drilled and the number and thickness of boards forming the stack. For example, two stacks of four boards for the Argus computer are reported to have been drilled (288 holes in each board) in 14½ minutes, i.e. an average time of 108 seconds per board, including loading and unloading.

Underground's underfloor lathe

AN UNDERFLOOR LATHE FOR MACHINING railway wheels has recently been brought into use at London Transport's Northfields depot on the Piccadilly Line. Designed and constructed by the Scottish Machine Tool Corporation to London Transport specifications, the new lathe can machine the whole profile of a wheel without the necessity for lifting the vehicle body from the bogies.

Drive is applied to the wheels by two pairs of rollers on vertical axes, the rollers being pressed hydraulically against the inner and outer faces of each tire. During machining, the weight on the axle is relieved by hydraulic jacks which are applied to the undersides of the axleboxes, while concentricity is assured by mounting the axle between live centres which have power-operated movement for raising them into the working position and for lowering again to positions clear of the rails when the vehicle is to be moved over the machine.

The machine works on the copying-lathe principle, i.e. the tool is moved by automatic hydraulic equipment across the wheel flange and tread, following a master profile. Quick power-traverse movement of the tool-slides in both directions is provided, together with steplessly variable ranges of speeds and feeds. Operations are controlled from a bank of push-buttons.



Underfloor wheel-lathe in operating position. Note press-button controls, drive rollers and tailstocks

In operation, the vehicle concerned (which normally forms part of a three- or four-car unit and is not uncoupled for the purpose of machining the wheels) is drawn forward on to the lathe by a power winch until the particular axle is correctly positioned. The tailstocks are then swung into position and locked, and the running centres are raised electrically, in combination, to a level slightly above the centre-line of the axle. The hydraulic jacks are then engaged and the axleboxes raised until the axle centres are in line with the tailstock running centres, which are then engaged with the axles and locked. Swing rails, used to bridge the operating position while train movements take place, are then moved clear and the tool-slides are traversed hydraulically to the operating position

and locked. The driving rollers are applied hydraulically and the cutting tools are raised electrically to the operating position.

After machining, the sequence is reversed to disengage the machine, and the vehicles are drawn forward to bring the next pair of wheels into position.

Recording sunlight at Kew

A unit for the continuous recording of radiation from the sun and sky, daylight intensity and diffused radiation, is now in use at Kew Observatory. Constructed by Lintronics Ltd, the equipment accepts a series of low-level signals ranging from −15mV

Kew Observatory's sun radiation unit by Lintronics Ltd incorporates a Honeywell recorder

to +15mV, from transducers, and feeds these to a Honeywell recorder at the rate of twelve a minute. Each signal is registered on the recorder and converted into three-digit numbers by a digitizer for visual display and punching into paper tape. The recorder will operate for three days without attention and is fitted with a 24h clock which records the time prior to each minute of measurement. The tape output is suitable for feeding into a digital computer in order to calculate hourly and daily mean values of the quantities measured. Eventually temperature and other variables will also be recorded.

Weighing moving wagons

An electronic weighing system designed by the American concern Fairbanks Morse & Co., is now in use at the Leatherwood, Kentucky, U.S.A., mine of the Blue Diamond Coal Company. The equipment weighs loaded railway wagons as they roll over a 20ft rail scale, and feeds the resulting information into a totalizing printer which automatically prints out both gross and net weights.

The coal-loaded wagons are uncoupled and allowed to roll down a 2% gradient on to the weighing rail, each wagon's weight from both front and rear axles being recorded while it is on the move. After each wagon has been weighed, it is automatically coupled to form a train.

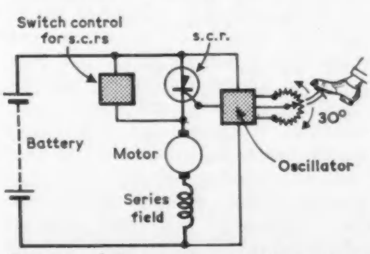
It is reported that the Louisville and Nashville Railroad, which accepts the weights recorded at the pit head for billing purposes, recently carried out trials to verify the accuracy of the system under normal operating conditions. After comparative tests, during which loads were weighed first in motion and then stationary, they are said to have fully endorsed the system.

Designed for a full capacity of 220,000 lbf, the automatic weighing system employs hermetically sealed load cells.

S.C.R.-controlled vehicle

A new electric truck by Smith's Delivery Vehicles Ltd, and known as the Transitruck, has stepless speed control using silicon controlled rectifiers in conjunction with a variable oscillator. Normally, battery-powered electric vehicles employ a resistor-shorting method of speed control which means, of course, that power is dissipated as heat through the resistors on starting.

The transistorized speed controller, which was developed by Joyce, Loebl & Co., Gateshead, is understood to provide smooth, loss-free control eliminating the wasteful starting resistance. The much-simplified diagram gives an idea of the system. Foot-



Transistorized control system for battery-powered electric vehicle—much simplified

pedal operation controls the frequency of an l.f. oscillator feeding the gating control electrodes of paralleled s.c.rs, so firing the s.c.rs at the required frequency. A circuit in parallel with the s.c.rs acts as the switching control for them. This is an inductance-capacitance arrangement which receives a delayed signal from the oscillator, and acts to switch off the s.c.rs, so varying the pulse-width and thus the mean voltage applied to the d.c. traction motor.

Fuller details of the control system have not been revealed as yet.

Hydraulics and the P.1127

The prototype Hawker P.1127 v.t.o.l. aircraft (these columns last month) has hydraulic power control units by the Hydraulics Division of Fairey Engineering Ltd. Three such units provide power for the ailerons and tailplane, and are able to meet the demands of an automatic stabilizing computing system. In other words, any tendency to yaw, pitch or roll is sensed by rate gyros and signalled through the electrohydraulic systems to hydraulic jacks, although this automatic system will always yield to manual input command from the pilot. Each unit is duplicated, and can accept the usual direct-input commands from the pilot, and it is reported that many of the P.1127's transitions have been made

Fairey hydraulic power control unit for the Hawker P.1127 v.t.o.l. aircraft

under the control of the pilot in more or less conventional fashion.

The three units can also accept signals from the autopilot directly, the pilot having preset the required course and altitude. Signals from the autopilot are fed to an electro-hydraulic servo-valve which controls the hydraulic units.

TURBINE AS A POWER SERVO

Under this heading in the September issue of *Control* there was a reference to an account of the helicopter turbine as a power servo, which was incorrectly reported to have appeared in *Control* in September and October 1959. This article, *The helicopter turbine a power servo* by A. W. Morley, appeared in the November and December 1959 issues.

NEWS ROUND-UP

from the world of control

SPACE

Hawker Siddeley unmanned

The news that Dr W. F. Hilton head of Hawker Siddeley Aviation's astronautics section has been dismissed, along with most of his team, has come as a severe shock to those who hoped for a British stake in the communications satellite business. Such work as will continue in the Hawker Siddeley group, appears to have been moved to de Havilland under G. K. C. Pardoe of Blue Streak fame. Lack of Government support is given as the reason for breaking up Hilton's team.

Earlier this year (these columns, March) Hawker Siddeley produced a voluminous report, *Industry and Space*, in collaboration with the French organization, Sereb. The company is also a member of the British Space Development Co. Ltd. (See February and May.)

BUSINESS

Solartron re-sold

Firth Cleveland, who acquired a 53·125% controlling interest in Solartron early in 1960, and subsequently increased their holding to 56·7%, have sold that interest to an American organization, Schlumberger Ltd. According to the financial press, Firth Cleveland made a profit of around 40% on the deal, their sale to Schlumberger bringing in £1,928,000.

As to the reasons for this sale, it may be assumed that Firth Cleveland felt that a 40% profit with £2m in hand was to be preferred to an electronics concern which had not produced any great profit in the past. Schlumberger, on the other hand, which has links with the oil industry, very large dollar assets, and appears to be about to merge with the U.S. Daystrom electronics concern, obviously wants an electronics foothold within the British and European (Common) markets.

Solartron is a firm of great promise and advanced ideas. That this promise has not as yet been fully realized—at least in terms of profit—may well have been due to the lack of financial backing. Perhaps the U.S. Schlumberger concern will be able to rectify this lack.

Cambridge's new wing

Another stage in the expansion program of the Cambridge Instrument Co. was marked by the official opening of their new instrument wing—an additional 15,000 ft²—last month. Cambridge Instrument's expansion has been most noticeable during the past year or two: in May 1959 their head-office accommodation was doubled, and new research laboratories opened in Cambridge in October of the same year; there were extensions to their Muswell Hill (London) factory in January and May 1960, and in June 1960 the company purchased Electronic Instruments Ltd, Richmond.

Much interesting work is going on at Cambridge Instruments at the moment. The measurement of carbon monoxide in road tunnels is one example: a sample of the suspect air is passed over a catalyst, and the resulting rise in temperature due to combustion of the carbon monoxide, is measured using resistance thermometers.

For boiler feed-water analysis there is an electrochemical dissolved oxygen analyser capable of measuring, continuously, 1 part oxygen in 10^9 parts water by weight, a dissolved hydrogen analyser, recording pH meters, conductivity recorders and, now under development, equipment for the continuous recording of CO_2 and residual hydrazine. Another development is a multi-point feed-water analyser which can record up to twelve separate variables such as dissolved oxygen and hydrogen, pH, conductivity, etc.

Measuring combustion efficiency

A combustion efficiency meter, the prototype of which is now on trial in a C.E.G.B. power station, records an index of combustion efficiency based on the chemical composition and temperature of the flue gases and the type of fuel used. Oxygen content is measured by a magnetic oxygen meter and the temperature by thermocouples; small quantities of combustible gases are determined by a katharometer. These three values are fed to a computer circuit together with the predetermined calorific value and carbon and hydrogen contents of the fuel. A four-point recorder gives continuous records of oxygen content—0–10%, temperature—0–500°F, combustible gas content—0–10%, and combustion efficiency—75–100%.

CONFERENCES

I.E.E.–R.Ae.S. control

A conference on *The importance of electricity in the control of aircraft* is to take place in London from 26–28 February, 1962, under the auspices of a Joint Committee of The Institution of Electrical Engineers and the Royal Aeronautical Society.

The subjects to be discussed include: the degree of reliability required of such systems as those concerned with auto-landing, vertical take-off, landing and supersonic flight, and how this reliability might be achieved; automatic flight control; airborne navigation systems; engine and fuel control; electrical systems in present aircraft; possible developments in electrical supply systems; the temperature problem in supersonic flight and its relationship to future electrical and electronic equipment; new techniques for future aircraft.

Further details are available from the Secretary of The Institution of Electrical Engineers, Savoy Place, London, W.C.2.

Information theory

An international *Symposium on infortion theory,* sponsored by the Professional Group on Information Theory of the Institute of Radio Engineers, and organized by the Benelux Section of the I.R.E. and the Belgian Society of Telecommunication and Electronic Engineers (S.I.T.E.L.), is to be held in Brussels, Belgium, from 3–7 September, 1962. The tentative list of subjects includes: coding and decoding of digital and analogue communication; studies of random interferences and of information-bearing signals; compression; analyses and design of communication and detection systems; pattern recognition, learning, and adaptive filters; automata and other forms of information-processing system; processing of sensory informa-

tion, and the human operator; nervous systems; linguistics; scientific method.

It is hoped to print all the papers before the Symposium is held. Abstracts (by 15 January) and papers (by 15 April) should be submitted to the Chairman of the Organizing Committee, F. L. Stumpers, Philips Research Laboratories, Eindhoven, Netherlands.

Computation and control

The International Association for Analogue Computation (A.I.C.A.), the French Association of Automatic Control (A.F.R.A.) and the French Association for Computation and Data Processing (A.F.C.A.L.T.I.) are planning a colloquium on *The techniques and applications of electronic computation in industrial automatic control*, to take place in Paris from 28 May to 1 June, 1962.

Apart from the techniques of analogue and digital computation, including hybrid techniques, their present and near-future limitations and reliability, particular emphasis will be given to industrial applications of automatic control, either as an aid in research and design, or as an integrated part of an automatic control system in connexion with, for example, optimization problems.

Those wishing to present papers should write to A.F.R.A., 19, Rue Blanche, Paris 9e, before 15 December, enclosing summaries of their projected papers.

PROFESSIONAL

B.N.E.S. formed

A British Nuclear Energy Society will be formed on 1 January, 1962, this new society succeeding the British Nuclear Energy Conference. In the words of Sir Leonard Owen, Chairman of the existing B.N.E.C. 'The Board of the Conference feels that the time has now come to provide a central forum for the discussion of nuclear energy and it is for this purpose that the British Nuclear Energy Society has been established'. Membership of the new B.N.E.S. is open to members of the constituent societies of the B.N.E.C., and to those who satisfy the Board that they are 'actively engaged in the professional, scientific, or technical aspects of the application of nuclear energy and ancillary subjects'.

There is an obvious parallel between the existing B.N.E.C. and the B.C.A.C.—the British Conference on Automation and Computation. The nuclear engineers have found it necessary to band themselves together into a Society; some control engineers feel a similar necessity for a new organization.

DATA PROCESSING

Computer sales increase

Last month's computer show (see page 99) has led to a great deal of news on the subject of sales of computers, if not, indeed, to the sales themselves.

Atlas for London

As was rumoured, London University is to install a Ferranti Atlas, perhaps 'the world's most powerful machine', in the Computer Unit in Gordon Square, W.C.1. Costing some £2m, of which British Petroleum are providing about a quarter, the Atlas should be operational by late-1963.

London's Atlas will be the third machine of its type. The first production model is now being assembled and commissioned at Manchester University, and should be available for use early next year, and a second machine has been ordered by the National Institute for Research in Nuclear Science and should be in operation at Harwell during 1964.

The London Atlas should be nearly 100 times faster than the Ferranti Mercury computer the University has been operating since 1959, has a much greater capacity for handling numbers, and also has facilities for storing large quantities of data on high-speed magnetic tape units.

Plessey's memories

A contract worth about £450,000 has been received by Plessey for further ferrite-core memory systems for the Ferranti Atlas. This memory system was developed by Plessey in collaboration with Ferranti and the team at Manchester University under Professor T. Kilburn. Some idea of the scale involved is apparent from the fact that the second Atlas on order (the Harwell machine) is to cost about £3·5m, of which the memory system will account for £350,000.

Stretch for U.K.A.E.A.

The United Kingdom Atomic Energy Authority has contracted with I.B.M. for a Stretch computer to be installed in 1962. The Authority is already using I.B.M. 704, 709 and 7090s.

The first Stretch was installed earlier this year at Los Alamos Scientific Laboratory of the University of California which is operated for the U.S. Atomic Energy Commission. Dr Bengt Carlson of that Laboratory is reported to have called Stretch '. . . the most powerful computer that is likely to appear for several years' (but see also, Atlas, above).

KDF9s for universities

The Universities of Birmingham, Glasgow, Leeds and Liverpool are each to install an English Electric KDF9 high-speed data-processing system. The value of these orders is about £1m.

22 Elliott machines

Elliott-Automation report that eighteen National-Elliott 803 computers, three NCR 315s and one National-Elliott 405—22 machines in all—have been ordered since midsummer.

Elliott's appear to have done very well, for, excluding the three NCR 315s, 126 National-Elliott computers had been ordered by last September, of which ninety had been delivered. Furthermore, one-third of these orders were for export.

Exports by I.C.T.

International Computers and Tabulators report substantial orders for computers and punched-card equipment from several countries overseas. The Singapore City Council have ordered an I.C.T. 1301 costing £70,000, and the Central and National Bank of Egypt £100,000-worth of punched-card equipment; the Egyptian Government have placed a further order for 80-column punched-card equipment.

From Germany came an order for an I.C.T. 1202 which is to be used by Werner and Mertz, Mainz, for invoicing and accounting.

Eire provided two orders, the Dublin firms of John Fisk and Sons and the Arklow Pottery Co. wanting punched-card equipment.

Electronic Data Processing Ltd, New Zealand, a data-processing service organization, have ordered a 1301.

National Provincial's order

Last May, I.C.T. concluded a long-term marketing and manufacturing agreement with the National Data Processing Corp. of Dallas, Texas, and their first order for that concern's equipment has just been received. It is from the National Provincial Bank, who are to rent equipment for sorting cheques and automatically listing the amounts encoded in magnetic ink.

I.C.T.–R.C.A. agreement

The Radio Corporation of America and I.C.T. are to exchange, 'non-exclusively' technical information and patents in the field of data processing. Presumably the agreement is non-exclusive because English Electric already have access to R.C.A. designs

through their subsidiary Marconi's Wireless Telegraph Co. who have worked in harness with R.C.A. since the latter concern was first formed.

Quite apart from this, there is, of course, an R.C.A. agreement with the French concern Compagnie des Machines Bull—de la Rue Bull in this country—and the French firm is thought to have ordered about $60m-worth of R.C.A. computers.

Recently I.C.T. have ordered fifty R.C.A. machines and are reported to have options on a further fifty.

NEWS BRIEFS

Servo-mechanisms and automatic controls, a five week course from 20 March 1962, is among the courses in Applied Mechanics at the University of Sheffield. Details: W. A. Tuplin, Professor of Applied Mechanics, University of Sheffield, St. George's Square, Sheffield, 1.

Eighteen control centres valued at about £70,000 have been ordered by C.J.B. from A.E.I. for use in two projected Russian detergent plants, one at Volgadonsk and the other at Shebekino.

E-A Space and Advanced Military Systems Ltd has been formed by Elliott-Automation to parallel in the non-industrial field the work of E-A Automation Systems Ltd.

Kollsman Instrument Ltd has been formed in the U.K. to handle the astro compass, instrumentation, and navigation systems of Standard Kollsman Industries Inc., Chicago, U.S.A.

Instrument maintenance will be the subject of a discussion group under the chairmanship of R. J. Redding, at the First National Maintenance Conference, Central Hall, Westminster, London, November 13–16.

Communications satellites: Brush Electrical Engineering have received a contract from the Post Office for control equipment, motors, generators, and servos for a steerable aerial now under construction at the Goonhilly Downs Post Office Radio Station, Cornwall. The 85ft diameter steerable paraboloid aerial will be used to track communications satellites in the joint P.O.–U.S. programs, Projects Relay and T.S.X.

STEEL

Instrumenting rolling mills

During a recent visit to Davy and United's Darnall Works, Sheffield, *Control* saw a great deal of control engineering interest. Both Davy and United Engineering and Davy and United Instruments are now members of the Davy-Ashmore group through the merger with Power-Gas.

It was Davy and United Instruments Ltd, however, with which we were most concerned. This company designs and manufactures special measuring and control instruments for the steel industry, being best known for automatic gauge control—the 'Gaugemaster' system. Automatic gauge control is employed, for example, on Steel, Peech and Tozer's recently commissioned four-stand tandem mill, described by J. C. Smith and I. C. Ross in *Control of a modern cold rolling mill,* which appeared in the September issue of this journal.

Apart from gauge control, the instrument company's products include loadmeters for measuring rolling loads, tensionmeters for measuring strip tension, widthmeters (narrow and wide), lengthmeters for measuring any length on the fly, nucleonic and X-ray thickness gauges, liquid-level gauges, forging-press position controls, and load cells for weighing.

A number of interesting contracts are under way at the moment. Eight gamma-ray thickness gauges are being produced for use in Russian plate and strip mills. Automatic gauge control is being provided for a four-high cold reversing mill at the Steel Co. of Wales' Newport Works, and, together with complete instrumentation, for a four-stand cold-strip mill at the Gartcosh Works of Colvilles Ltd. They are also providing seven sets of load-meters for a John Summers' hot-strip mill, several thrust-measuring equipments for test beds for Rolls-Royce jet engines, and a variety of load-cell equipment for weighbridges, crane-weighers, chemical tanks, and hoppers.

LABOUR

Too many scientists?

The crippling shortage of scientific manpower experienced in this country since the war, may well come to an end within the next three or four years, according to the Statistics Committee of the Advisory Council on Scientific Policy as reported in *The long-term demand for scientific manpower* (H.M.S.O., 1s. 9d. net) This is the Committee's main inference, although they warn that the evidence at their disposal, particularly in relation to future demand for employment, was not precise enough for detailed conclusions to be drawn.

At the moment, however, there is still a shortage of scientists and it is felt that this will continue for a long time in the educational world, and where mathematical skill is required.

The obvious assumption has been made that the demand for qualified manpower in the technologically advanced industries slackens when the technologies concerned are fully manned. When this happens, manpower demands will depend upon the size of an industry, that is until such time as hypothetical technological changes present a new industrial situation. The Committee feel that certain advanced firms in leading industries in both the U.S.A. and here, are already exhibiting this tendency towards scientific-manpower saturation. They have assumed, therefore, that the density of scientific manpower within these industries will rise to the level already characterizing the 'best' firms.

It is further suggested that the number of qualified persons per 1000 of working population will rise from seven to thirteen during the next ten years, and that this doubling will be exceeded in many industries.

To sum up: the Report concludes 'that the overall supply and demand for qualified manpower will not be very much out of balance at the end of the first five years of the decade 1960–70. If anything, a slight shortage of technologists will be balanced by a slight surplus of scientists . . .'

NEWS BRIEFS

Inertial Guidance-Europe has been formed in Paris by British Aircraft Corp. and Minneapolis-Honeywell Regulator to develop, manufacture and market inertial guidance systems for aircraft and missiles in Europe. Manufacturing resources include those of English Electric Aviation at Stevenage, and Honeywell facilities in Frankfurt, Germany, and in Britain.

Auto-testing the Lightning: Honeywell systems analysers have been ordered for use with the R.A.F.'s Lightning aircraft.

R.T.B.'s Spencer Works: 17 weighers for materials passing over belt conveyors, together with equipment for transmitting the weights continuously to remote instruments, have been ordered from Craven Electronics. Honeywell Controls' temperature, flow, pressure and oxygen-analysing equipment for re-heating and heat-treatment furnaces, together with instrumentation for lime kilns, ore dryers, pickle line, acid recovery, *etc.*, is also to be installed at Spencer Works.

Dip. Tech: A list of 113 courses (at 27 colleges) recognised as leading to the Diploma in Technology has been published by The National Council for Technological Awards, 24 Park Crescent, London, W.1.

On-line application of digital computers to continuous operations is being tackled by the new Special Computer Division of Elliott Brothers (London) Ltd.

Cambridge–C.G.S.–S.p.A., Casoria, near Naples, has been formed by Cambridge Instrument Co., and Istrumenti di Misura C.G.S., S.p.A., Monza, Milan, Italy.

Hagan Controls Ltd is now at Weedon Road, Northampton (telephone, Northampton 260).

PEOPLE IN CONTROL

by Staffman

J. M. Storey, Chairman of the Council of British Manufacturers of Petroleum Equipment, speaking at the Council's annual dinner recently, announced that the Institute of Chemical Engineers, the Society of Chemical Industry and Imperial College would be running symposia in parallel with next June's Chemical and Petroleum Engineering Exhibition at Olympia. After that, guest-speaker **Kenneth Horne** (self-styled 'occasional broadcaster') just had to divert the minds of the diners, and this he did with some remarkably sustained on-stream control of continuous-flow humour. My illustration (above) shows him in full spate. Storey is to his left.

Now visiting the U.S.A., three executives of Ultra Electronics, **A. V. Edwards** (Managing Director), **F. W. Stoneman** (Executive Director Sales and Engineering), and Major General **E. S. Cole** (Operational Manager of Ultra's newly formed Telecommunications Division), are having further discussions with the two American directors of Ultra, **N. H. Jacoby** and **J. M. Petit**. The latter are both directors of Electronics Capital Corp., San Diego, and of Electronics International Capital Ltd, the Bermudan financial concern which holds a 40% interest in Ultra Electronics. Jacoby is Professor and Dean of the University of California, and Petit is Dean of the School of Engineering and Professor of Electrical Engineering at Stanford University, California. Petit is no stranger to the British scene for he was at one time Assistant Technical Director of the American British Laboratory (U.S. Office of Science Research and Development at Great Malvern—a T.R.E. offshoot I presume. Major General Cole joined Ultra to head their Telecommunications Division quite recently. He was Director of Telecommunications at the War Office. I gather that his new Division will not only be able to take advantage of Ultra's own facilities but also those of both W.S. Electronics and Trix Electronics.

Lord **Brabazon** (below) chided British industry for its slowness in applying computer techniques, when he opened the Electronic Computer Exhibition at Olympia last month. He pointed out that there were about 1000 computers in use on the Continent, compared with 350 in this country. He went on to say that a computer is not a luxury but a necessity if Britain is to compete. I think we all sympathize with his criticism of British conservatism and slowness in applying computers.

Incidentally, **R. J. A. Paul** reviews the computer show on page 99.

Not a luxury

Broadcasting and oil

Data transmission and coal

D. W. Hooper, Chief Organizing Accountant of the National Coal Board and, of course, President of the British Computer Society, visited Marconi's, Chelmsford, recently to discuss data transmission equipment. In my photograph (above) he is examining such equipment in company with **A. R. Laws** (left), Sales Manager of the company's Communications Division, and **B. Mayson** (right), Assistant Chief of Sales Group. Marconi's assure me that the type HU 131 equipment under discussion 'is the only data transmission equipment to be developed in this country for the transmission of punched card information with error correction by automatic repetition'.

Now Manager of the Computer Engineering Department of A.E.I.'s Electronic Apparatus Division, Trafford Park, **J. C. Gladman** joined Met-Vick's Radio Department in 1948 and worked on airborne radar, g.w. telemetry, and digital computer design and application.

Gladman studied electrical engineering under Sir **Willis Jackson**, who was then at Manchester. It will be recalled that Sir Willis left Manchester to become Professor of Electrical Engineering at Imperial College in 1946, and rejoined Met-Vick (now A.E.I. (Manchester)) in 1953 as director with responsibility for education and research. As I mentioned last month, Sir Willis is now Professor of Electrical Engineering at Imperial College once again.

K. Gordon Sinclair, Chairman of the Griffin & George Group, has just announced the appointment of **Dennis S. Beard** to the board of Griffin & George (Sales) Ltd as Technical Sales Director. Beard took a degree in physics at Imperial College and, after a period in the Department of Naval Construction as administrative head of the Radio-

graphic Section, was awarded an I.C.I. Research Fellowship in Chemistry at Leeds University. From 1951–54 he was with N.R.D.C., and in 1960 he joined his present firm from Norwich City College where he lectured on physics and mathematics.

Other Griffin & George news includes the appointment of **W. J. Bates**, a well known figure in the optical world, as Chief Engineer of R. & J. Beck Ltd. He joins Beck's from Bristol University.

A. C. Jones, who was Manager of the Audco Controls Division of Audley Engineering, has joined Elliott Brothers as Assistant General Manager within the Automatic Control Valve group. Jones spent several years in the U.S.A., with firms in the instrumentation and control field, and subsequently held various posts with Babcock and Wilcox.

Dr **H. H. Rosenbrock**, well known for his many contributions to process control (and to *Control*), has gone up to Cambridge University to do D.S.I.R.-sponsored research in the Engineering Laboratory's Control Group. Dr Rosenbrock will continue his directorship of Automatic Control Engineering Ltd, with whom he will be keeping in touch. In this way he hopes that his researches will be firmly anchored to industrial reality and he will not wander off too far along academic bypaths.

As you probably know, A. C. Cossor Ltd was purchased by Raytheon Co. of Massachusetts, U.S.A., the other day, and now I hear of the to-be-expected elections to Cossor's Board. **Charles Francis Adams**, Chairman of the Raytheon Board, **Richard E. Krafve**, Raytheon's President, and **Carlo L. Calosi** have all joined the Cossor Board. However, Major General Sir **Miles Graham** continues as Cossor's Chairman, and **James S. Clark** as Managing Director, and Raytheon have stated that they do intend to preserve the identity of the Cossor group.

AUTHORS IN CONTROL

A. E. De Barr (*Machine tools in transition*, page 88) is Director of Research of the newly formed Machine Tool Industry Research Association. He is a physicist who graduated from Leeds University in 1939. During the war he served in the Mine Design Department of the Admiralty, and has since worked in the research departments of Guest, Keen and Nettlefolds, Elliott Brothers (London) Ltd, and latterly at the Shirley Institute (Cotton, Silk and Man-made Fibres Research Association) where he initiated work on the application of automatic control to cotton spinning machinery. His interest has always been in the application of scientific research to industrial problems, and he has published papers on a variety of subjects ranging from magnetic materials and X-ray crystallography to the physics of cotton spinning. He is a Fellow of the Institute of Physics, and has interested himself in the educational aspects of the Institute's work, serving for many years as an examiner for the Graduateship examination, and on the Joint Committee for National Certificates in Applied Physics.


REDDING


DE BARR

G. M. E. Williams (*Machine tools—design and research*, page 93). See page 113, February 1961.

R. J. Redding (*Electronic hybrid amplifiers for industrial temperature measurement*, page 95) studied electrical engineering and telecommunications at the South East London Technical College. In 1938 he was apprenticed to Elliott Brothers (London) Ltd, where he later worked on telemetering equipment. He joined Evershed & Vignoles Ltd in 1951 as a development engineer concerned with the design and development of industrial electronic process control equipment, becoming Head of Development and Chief Technical Engineer of the Instrumentation and Control Division. He joined the Technical Group of Constructors John Brown in 1961 as Senior Engineer for Instrumentation and Control. Redding is a Council Member of the S.I.T., and Vice-chairman of its Control Section.

R. J. A. Paul (*Trends in computers*, page 99). See page 128, October 1961.

Andrew D. Booth (*Progress in automatic language translation*, page 103). See page 128, October 1961.

A. G. S. Pask (*Cybernetics becomes well-defined science*, page 106) attended Rydal School and Liverpool Technical College studying geology and chemistry. He then went to Downing College, Cambridge, where he read physiology and psychology. After graduation, he founded System Research Ltd. Pask has designed various learning machines, originated adaptive teaching systems, and has worked upon brain analogues and various self-organizing systems. Currently he is directing a group instruction project sponsored by Wright Field, U.S.A.F., and is a consultant in cybernetics. He also paints and writes revue lyrics along with obscure (*sic*) scientific papers.


CARTER


PASK

S. Demczynski (*Production control and machine loading in a jobbing shop*, page 109). See page 128, October 1961.

E. J. Bishop (*Voltage-sensitive relays*, page 112) served an electrical engineering apprenticeship at J. W. Russell Ltd from 1943 to 1948, and followed this by two years as a radar mechanic in the R.A.F. From 1950 to 1953 he ran his own business, then joined Transformers (Watford) Ltd as a test engineer. He left them in 1955 to work as a development engineer at S.T.C., and in 1957 he joined Advance Components as a senior development engineer. There he is at present engaged on the design and development of constant voltage transformers and stabilized power supplies.

R. J. Carter (*A chromatographic closed-loop control system*, page 119) was educated at Newport (St Julien's) High School for Boys and the University of Birmingham, where he graduated with honours in physics in 1951. He served as a Lieutenant Instructor in the R.N. from 1951–54, gaining 'Full Technological Certificate: Telecommunications Engineering'. Since 1954 he has worked in the chemicals and plastics industry on instrument maintenance and plant starting-up (mainly the latter). He is now Instrument Manager of the H.O.C. Division of I.C.I.'s Olefine Works at Wilton, Yorkshire. Carter says, 'I was particularly fortunate to have spent my first few years working for Mr W. C. Richards of Monsanto Chemicals Ltd, whose dedicated, professional attitude to instrument engineering led to my own enthusiasm for plant instrument engineering'.

New for the user

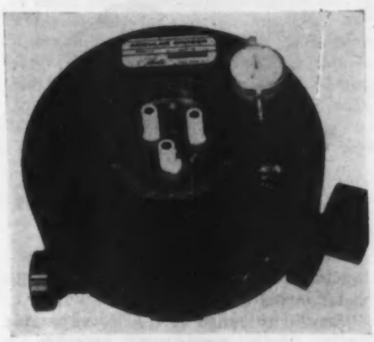
A monthly review of instruments, components, equipment and machinery for automation

For further information, circle the appropriate number on the reply card facing page 160

ANGULAR DIVIDER

high overall accuracy

Made by Theta Instrument (U.S.A.), the model D-4 angular divider is intended for the precise angular positioning of synchros, resolvers, potentiometers etc.



Robust

Standard overall accuracy is 15", and models may be selected with accuracies down to 5". Repeatability is 6" for standard models and 2" for specially selected models.

The coarse mechanism has a master plate with 72 notches spaced at 5° intervals. The fine mechanism has a range of ±2·5°, with full-scale reading ±25' on a 2½in, 100-division dial.

Circle No 580 on reply card

PHASE METER

audio and sub-audio frequencies

The type 630 phase meter, by Dawe Instruments, measures the phase-difference between two electrical signals in the audio and sub-audio frequency range. The scale is directly calibrated 0 to 360°, and accuracy with balanced signals is quoted as better than ±3% above 10 c/s. Frequency range is 1 c/s to 25 kc/s, and attenuators provide sensitivities and input impedances ranging from 30–300V r.m.s. into 10MΩ, to 30–300mV r.m.s. into 10kΩ. The unit is portable, and will operate from 100–125V or 200–250V a.c. mains, or from internal batteries which give about forty hours' operation.

Circle No 565 on reply card

MAGNETIC TAPE UNIT

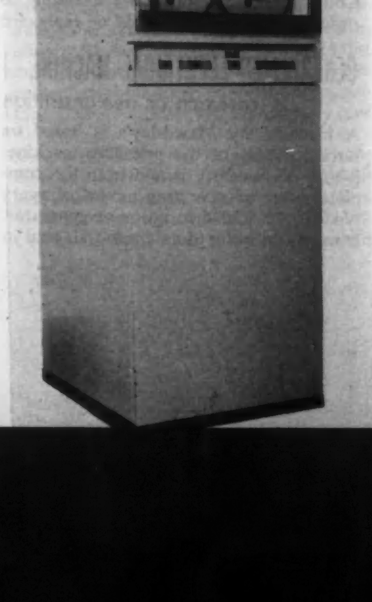
digital computers

Decca's type 4000 tape-unit is designed for use with digital computers and data-processing systems. The spools accommodate up to 3600ft of tape, and the tape transport may be specified for handling 1in- or ½in-wide polyester or sandwich tape of 0·0015in overall thickness. The range of tape speed is 30in/s to 150in/s, and maximum speed deviation is ±5% at 150in/s. Start, stop, and reverse times are quoted as 1½, 1½, and 2½ms respectively, maximum variation of each being ±½ms; the tape drive is rated for continuous operation in any duty cycle.

All switching and amplifier circuits are completely solid-state, and no relays or brush motors are used. The cabinet is approximately 6ft 2½in high, 2ft 1in wide, and 2ft 5in deep; power supply required is 400V, 50 c/s, three phase. (*A note on this unit appears in this month's* Ideas applied.)

Circle No 563 on reply card

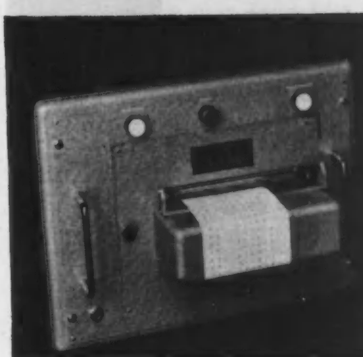
Solid-state



ELECTROMECHANICAL PRINTER

2 lines/s maximum

Printers by Wetzer K.G. (Germany) are available in the U.K. from General Precision Systems. They are assembled from prefabricated parts, making it possible to adapt the printing elements to any requirement. Both the counting units and the type wheels are available in groups of 2, 4, 6, or 8, and may be arranged to print added results, consecutive numbers, and dates and time, all at a maximum speed of 2 lines/s.



Flexible

The illustration shows a printer with two groups of type wheels: one of two digits, for counting consecutive numbers, and one of six digits. The printers can be supplied either as table models or for mounting in standard 19in racks.

Circle No 550 on reply card

GLOBE VALVES

pneumatic or hydraulic operation

A globe valve by Perret Control has a maximum working pressure of 125lbf/in², and will handle cold non-corrosive liquids or gases. It is operable by either hydraulic or pneumatic power, from 40–100lbf/in².

The valve uses line-pressure to assist closure, and the system employed tends to eliminate shock. The Hydrovalve is available in sizes ranging from 2in to 3in, with B.S.P. and N.T.P. threads and flanges. (*A note on the operation of this device appears in this month's* Ideas applied.)

Circle No 539 on reply card

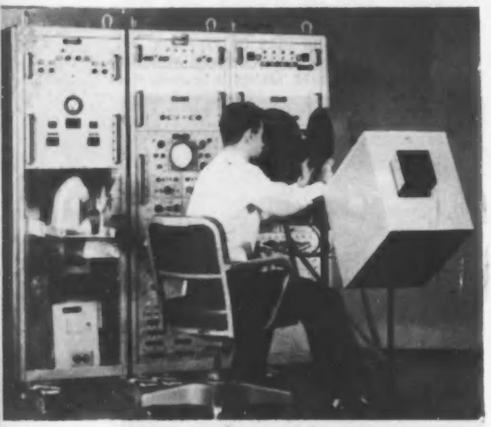
TRANSIENT ANALYSIS RECORDER

3 c/s to 22 Mc/s

A transient analysis recorder, by General Dynamics/Electronics (U.S.A.), is intended for the photographic recording of complex video signals; it uses a double-beam oscilloscope. The phosphor rise- and decay-time and trace-intensity of the tube allow sweep-speeds up to 0·5μs/cm, at repetition rates up to 200 kc/s; this

permits the recording of pulses 0·1μs wide with rise-times down to 19mμs.

Coded information signifying time of day, sweep-rate, vertical sensitivity, and video-input position, is automatically recorded on data tracks on the film edges. In addition, z-axis time-markers and standard-amplitude reference marker-pulses are available for presentation of the horizontal sweeps. Loading and unloading of the camera, and selection of any of four input-signals, may all be carried out at the operator's control panel. Monitoring is continuous and not interrupted by camera operation, and an optional unit allows photographs to be automatically processed within six minutes of taking.


Records 0·1μs pulses

Circle **No 548** on reply card

FLOWMETER
withstands high temperatures

Designed for use in heat-transfer systems using water or Terophenyl, a flowmeter by Meterflow will operate at temperatures up to 400°C. General construction is stainless steel, with silver-graphite bearings (98% silver).

Flow ranges now available are 0·3–3, 1–8, and 3–25 gal/min; pressure-drop in all ranges is approximately 5lbf/in² at maximum flow. Linearity is given at ±1%, repeatability as 0·2%. Maximum internal pressure is 3000lbf/in², and the output at maximum flow is approximately 1000 c/s. Units are made with screwed end-connexions, or with ends suitable for welding direct into the pipeline. Circle **No 532** on reply card

TUNED AMPLIFIER/NULL DETECTOR
20 c/s to 20 kc/s

A low-noise transistor amplifier, made by General Radio (U.S.A.), has a full-scale sensitivity of 1V, and tunes steplessly from 20 c/s to 20 kc/s. Additional fixed frequencies are also provided at 50 c/s and 100 kc/s.

The 1232-A amplifier is intended primarily for use as a bridge detector; it consists of three stages, with negative feedback through a null network having its null-point at the desired operating frequency. Since there is negative feedback at all frequencies but that desired, the overall response peaks at this frequency and is roughly equivalent to that of a tuned circuit with a Q of about 20 (5% band-width). It may be switched to have either linear or logarithmic amplitude characteristics.

Circle **No 576** on reply card

SHEAR REGISTER CONTROL
electronically operated

The Paton mk IV shear register control, made by Hird-Brown, is intended for use where roll-fed material is to be cut into accurate lengths. The unit consists of a control-amplifier unit, a light projector, and a photocell receiver. The projector and receiver may be used for either transmitted or reflected light, and may be adjusted to be sensitive to either an increase or decrease in illumination Hence, light marks on dark grounds or *vice versa* may be used as markers.

The control unit may be placed at any point within about 12ft of the projector and receiver; it includes a 5A double-pole, double-throw relay, and houses all necessary monitors and controls for brightness, sensitivity, etc.

Circle **No 541** on reply card

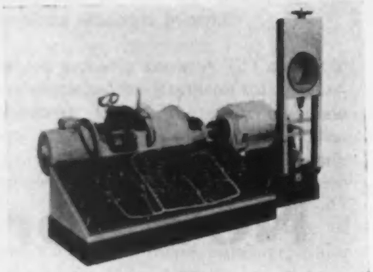
TIME-DELAY RELAY
solenoid operated

The MES/100 relay, by Industrial Instrument Services, has a solenoid-operated mechanical movement which operates a change-over switch at the end of an adjustable delay-time. Instruments can be supplied with manually-adjustable time-settings over the following ranges: 0–10, 0–30, 0–60, and 0–120s, and 0–5min. Switching capacity of the relay contacts is 5A at 230V, 50 c/s. Standard operating voltages are 100–110V, 200–250V, and 400–440V, 50 c/s. Coils for d.c. operation are available to order. Circle **No 557** on reply card


Variable delay

GENERALIZED ELECTRICAL MACHINE
research or demonstration

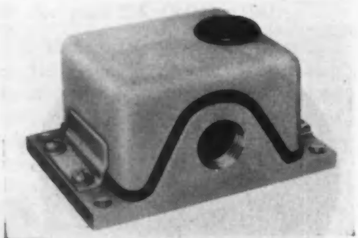
A machine by Mawdsley's is based on Kron's theory of the primitive machine; it may be used to demonstrate the complete range of operating modes of every type of a.c. and d.c. motor or generator. It may also be used as a research tool in post-graduate work. The complete set consists of the generalized machine, a d.c. machine, a torque-measuring unit, and an integral a.c. tacho-generator for measuring rotor speed.


Self-contained

Circle **No 573** on reply card

EXCESSIVE-VIBRATION DETECTOR
variable sensitivity

Electro Methods' Vibraswitch is a vibration-sensitive device with an internal switch which closes when vibration exceeds a preset level. The switch may be used to trigger an alarm system, or to shut down the equipment on which it is mounted. The sensitive axis is perpendicular to the mounting base.


Simple to adjust

Sensitivity range is 0–4·5g, adjustable by a single screw, and accuracy is claimed to be ±5% of full range from 0–300 c/s, or 18,000 rev/min. Contacts are rated at 7A, 460V a.c.; 0·5A, 115V d.c.; 2A, 48V d.c.; 5A, 24V d.c. The coil is rated 10 to 14W, intermittent duty, and, is available for nominal voltages from 6 to 115V d.c. Maximum energized time is four minutes.

Circle **No 546** on reply card

INSTRUMENTATION SYSTEM
digital on-line

Blackburn's Adonis automatic digital on-line instrumentation system has a number of basic units using plug-in modules for maximum system flexibility. A scanning unit switches thermocouple and other transducer inputs in sequence to common amplifying, measuring, recording and display equipment.

A wide range of units is available, and includes the following: scanning units, which allow scanning at rates up to 50 points/s; data amplifiers; linearizing and rate-change units, which compensate for non-linear transducer characteristics and

alter scale-factor to cater for mixed transducer sources; alarm detectors and level-setting units; reference power supplies; analogue-to-digital converters; keyboard units, permitting the introduction of manually-generated data; digital stores; digital display units; digital clocks, for initiating routine logs and providing time to the printer; program control units, which control the logical operation of the complete data-acquisition system; serializer; and various in-line digital printers, etc. Circle **No 537** on reply card

MOVEMENT INDICATOR

optical system

The Refractosyn, by H. H. Controls (U.S.A.), uses an optical system to measure and sense any movement of a target-mirror attached to the component under inspection. Indication is on a centre-zero meter, and a zero-setting control is provided. (*A note on the operation of this device appears in this month's* Ideas applied.)

Circle **No 560** on reply card

MAGNETOSTRICTIVE DELAY-LINE

2 to 20μs delay

A delay line by Selectro, the type 157, is steplessly adjustable from 2 to 20μs, adjustment being by a single multi-turn screw. Maximum pulse-repetition rate is 500 kc/s, and input pulse-width 1·0μs. Input and output impedance are each 400Ω; dimensions are 7 × $\frac{1}{2}$ × $\frac{13}{16}$in.

Circle **No 553** on reply card

VOLTMETER/COUNTER

digital indication

Southern Instrument's M.1155 meter measures voltage from 1mV to 500V d.c., and frequencies from 0·1 c/s to 120 kc/s using counting periods of 0·1, 1·0, or 10s. It will also measure time intervals, defined by electric signals or contact closures, from 1ms to 27·7h, and provide crystal-controlled clock-pulses of 0·1, 1·0, 10 and 100ms, and 1·0 and 10s. Projection-type in-line indicators provide a three-digit plus sign display, and a latching system, which is released momentarily at the end of each count, gives a continuous display uninterrupted during the counting period.

Circle **No 552** on reply card

ROTATION MONITORS

semi-conductor circuitry

Units by Pentechnique are intended for use in alarm systems to indicate when a monitored shaft (or any reciprocating or linear motion) slows down or stops. Pulses obtained from a magnetic transducer coupled to the shaft are used to hold a relay in. When the shaft stops, the relay is de-energized and the relay's contacts close. Warning lights are fitted, and the plug-in dust-proof relay has two-pole change-over contacts rated at 250V, 5A, a.c.

Special versions are available for use with switch contacts and photo-electric pick-ups, and for switching at specific shaft-speeds. Other modifications include the provision of alternative relays, power-transistor output-stages for direct operation of small solenoids, variable-delay pull-in and drop-out circuits.

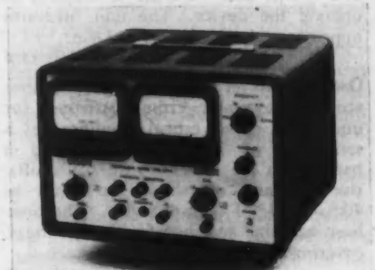
Circle **No 564** on reply card

IMPEDANCE COMPARATOR

four measuring frequencies

An instrument by Danbridge (Denmark) may be used for the production testing and sorting of components etc. Two meters indicate respectively impedance and difference in phase-angle between a known and an unknown component.

Measuring frequencies are 100 c/s, and 1, 10 and 100 kc/s; resistance or im-



Accurate to 3%

pedance may be measured from 1Ω to 50MΩ, and phase-angle differences in four ranges from ±0·006% to +30/−25% overall. Accuracy is claimed to be 3% of full scale reading. Power supply required is 110 or 220V, at 50 or 60 c/s. The type CPT.1 is available in the U.K. from Metrix.

Circle **No 558** on reply card

QUICK LOOKS

Millivoltmeter. Airmec's type 301 meter measures direct and alternating voltages over the ranges 100μV to 10V and 300μV to 3V respectively. Frequency range is 100 c/s to 100 kc/s using the l.f. input socket, and 50 kc/s to 900 Mc/s using a high-impedance probe. Power supply may be 100–125 or 200–240V, 50 c/s. Circle **No 569** on reply card

Automatic data writer. Ultra's series T2A50 Datawriters are conversions of Olivetti Lexikon 80E electric typewriters, the manual facilities of the machine being unimpaired. The conversion may be for numeric or for full alpha-numeric operation, and key switches and type-bar solenoids are fitted to provide facilities for use as an input or output writer. An additional set of keys may be fitted to allow remote control of an add/list machine for the generation of special control symbols when coupled to a paper-tape punch. Circle **No 570** on reply card

D.C. amplifier. An amplifier by Cubic Corporation (U.S.A.), the model 1010, is claimed to have an accuracy of 0·1% at fixed gain-settings of 10, 20, 50, 100, 200, 500 and 1000. A vernier control permits upward adjustments from any fixed-gain point. The circuitry is all solid-state and this, with full magnetic and electrostatic shielding, gives low-noise operation.

Circle **No 566** on reply card

Digital clocks, series 2500, by Chrono-Log (U.S.A.), are now manufactured with binary-coded decimal and decimal outputs, combined in the same clock. Time resolutions of minutes, tens of seconds and seconds are available.

Circle **No 542** on reply card

Storage tube. The Scan Convertor K.2070, by Dumont (U.S.A.), is available in the U.K. from Aveley. It is a double-ended unit capable of resolution in excess of 1000 lines at 5% modulation. Either simultaneous or sequential reading and writing may be used, and stored information may be held for hours, rapidly erased, or made to decay at a controlled rate while new information is superimposed.

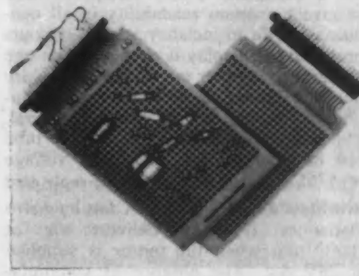
Circle **No 543** on reply card

Resolver standard. Available from Wayne Kerr is the Gertsch (U.S.A.) RS-1 resolver standard. When driven by a 400 c/s, 26V source, it produces the two output voltages of a master synchro as its shaft is rotated in 5° increments through 360°. Ratio accuracy is 2″, and effective series impedance is 0·01Ω. Models for frequencies and voltages other than 400 c/s and 26V are also available. Circle **No 544** on reply card

Polystyrene capacitors. A range by T.M.C. is intended for use in low-voltage and transistor circuitry. Capacitance values range from 0·0005 to 0·5μF, and sizes range from $\frac{3}{16}$in dia, by $\frac{7}{16}$in, to $\frac{13}{32}$in dia. by $1\frac{13}{32}$in. Power factor is not greater than 0·001 at 1 kc/s.

Circle **No 545** on reply card

Circuit cards. A series of cards for use in conjunction with edge-connectors are available from R.W. Furness. The cards provide a convenient mounting for standard components, and may be used for experimental and production circuits



without the expense of preparing specially designed printed cards. Sizes in stock include 6 × 4in and 8 × 6in cards for use with 0·150in pitch edge-connectors. Circle **No 568** on reply card

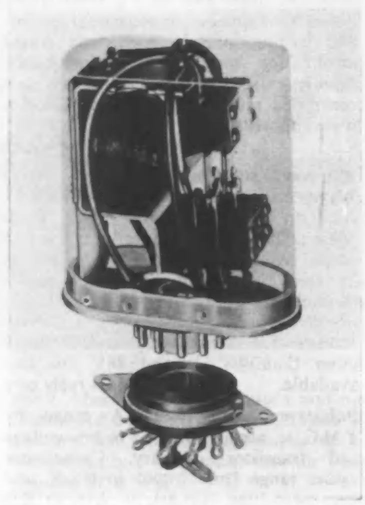
Gas and air mixers by Eclipse Fuel Engineering (U.S.A.), produce an air-gas mixture and deliver it under pressure to a burner or burners. They are for industrial heating installations where a

New for the user

blast pilot is desired and no other source of air-pressure is available. Less than 6½in in diameter, these fan-type mixers are made for firing installations requiring inputs up to 215,000 B.t.u./h. Inlet gas-pressure of $4inH_2O$ is adequate to give full rated capacity. Firing can be at a fixed rate, or automatic on–off control can be provided by installing a solenoid valve in the gas line feeding the mixer.

Circle **No 547** on reply card

Multi-contact relay. The DMP relay, made by Maughan, has a three-pole change-over contact arrangement, rated at 7·5A (1250VA) a.c., and 7·5A (500W) d.c. The plug-in base has silver-plated pins arranged to fit a 12E international



valve-holder. The coil is continuously rated at 2·3W, 8VA, and requires a 200–250V, 50 c/s, supply. The relay may be mounted in any plane, is claimed to have a high resistance to shock and vibration, and is flash-tested at 2500V, 50 c/s, between all circuits.

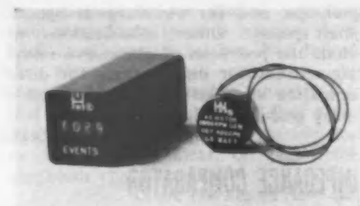
Circle **No 575** on reply card

Numerical indicator tube. A cold-cathode numerical indicator by Mullard, the Z520M, has a built-in optical filter to give maximum readability in all conditions. Life expectancy is 30,000 hours provided the display is changed from one numeral to another more than once every hundred hours, or 5000 hours for continuous display of any single numeral. The numerals are ⅝in high, and the tube can be operated with a supply voltage of 170V. Circle **No 538** on reply card

Brushless d.c. motor fan. A fan by Astro Dynamics (U.S.A.), delivers air at $100ft^3/min$ when the motor is supplied at 28V d.c. The absence of commutators and brushes reduces both electrical and accoustical noise and eliminates arcing, so allowing use in aircraft at high altitudes. A range of speed control is provided by variation of supply voltage from 20 to 40V d.c.; at 28V, the power consumption is 30W.

Circle **No 561** on reply card

Counter. A 'starts' or events counter by Haydon (U.S.A.) measures only $\frac{1}{2}in^2$ by 1⅝in long, and weighs 0·75 ounces.



It operates from a 28V d.c. supply, and the four-digit drum counter counts up to 9999. Circle **No 549** on reply card

Counter. A pneumatically-operated counter by Trumeter is of particular value where electrical equipment could constitute a fire hazard. It is connected directly into the air supply to the device, and counts each time air is supplied to operate the device. The unit measures approximately 4⅜ × 2¼ × 1⅞in.

Circle **No 533** on reply card

Oscilloscope. A general-purpose oscilloscope is available from Dartronic for under £40. The vertical amplifier has a sensitivity of 100mVr.m.s./cm, and a band-width of d.c. to 9Mc/s (−3dB); rise-time and overshoot are given as 40mμs and < 1% respectively. The time base has nine switched frequency-ranges, covering in all 0·12 c/s to 420 kc/s.

Circle **No 567** on reply card

Null indicators. Available from Wayne Kerr are two transistorized phase-sensitive null indicators by Gertsch (U.S.A.). Either model may also be used as an amplifier over the frequency range 25 c/s to 100 kc/s, with gain selectable at 50, 500, or 5000. Three sensitivity ranges are provided: 10,100, and 100μV. The NI-2 is a battery-operated portable model, and the NI-3 is a 3½in high, rack-mounting unit, which requires an external a.c. supply. Both models have a minimum input-impedance of 1MΩ, and reference-voltage ranges of 1 to 5V, 5 to 2·5V, and 25 to 125V are provided.

Circle **No 571** on reply card

Derivative units for pneumatic control systems are available from A.E.I. There are two models, the 59D and the 59R, for direct or inverse derivative action respectively; they are said to be maintenance-free provided the air supply is clean. Operating at a supply pressure of $25lbf/in^2$, the units have a derivative-time adjustment from 0·2 to 20 minutes; input and output pressure ranges are 3 to $15lbf/in^2$. Ambient temperature range is −60 to +200°F.

Circle **No 534** on reply card

Heat sinks, for soldering transistors without damaging them by overheating, are obtainable from A.N.T.E.X. They are small clip-on devices, which clamp the wire to be soldered.

Circle **No 535** on reply card

Fleeting-contact relay. Clifford and Snell's D.2600 plug-in relay may be fitted with a subsidiary relay, claimed to be of completely new design, which operates for 0·1s when the main relay is energized, de-energized, or both. Disadvantages of earlier types (using a mercury switch) have been eliminated, and the unit may be used in any position or in mobile equipment. The principal application of the D.2600/F is for fault-alarm circuits. Available from D. Robinson.

Circle **No 572** on reply card

Television camera. For closed-circuit television systems, a camera by Murphy will operate into any standard 405-line receiver. It normally includes a P828 Vidicon tube, and a 1in, *f* 1·9 lens, and is fitted with automatic sensitivity-control. A suitable monitor is available if required. Circle **No 559** on reply card

High-current supplies. Five transistor stabilized power-supplies by Kasama have maximum outputs of 10, 20, 30, 40, and 50A respectively, all with a steplessly-variable voltage range of 0 to 30V. Designated KTV/310 (10A) to KTV/350 (50A), source resistance is 0·003Ω, and ripple is 1mV peak-to-peak. Voltage and current are monitored on separate meters, and the units are provided with adjustable overload cut-outs. Outputs are fully floating, and the stability factor is given as 1000:1. Circle **No 540** on reply card

Switching diode. Available from G.E.C. is the GEX71 germanium gold-bonded high-speed diode. It is mounted in a sub-miniature glass case, and is claimed to have a very fast transient response. Maximum continuous reverse voltage and forward current ratings are 10V and 30mA respectively; maximum peak forward current (up to 5ms duration) is 100mA. Circle **No 574** on reply card

Counter units by Pentechnique incorporate an electromechanical six-digit counter, and a mains-operated power supply; they are designed to work directly from a transistorized magnetic transducer. They may also be supplied for use with

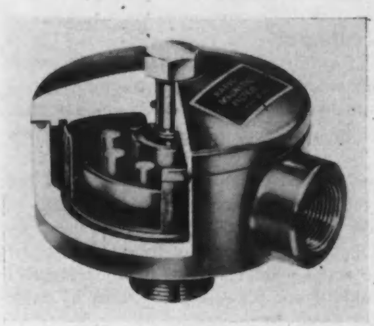
switches or photo-electric pick-ups, and both versions are fitted with mains switches and warning lights. Maximum counting rate is greater than 20 counts/s.

Circle **No 578** on reply card

High-speed printer. Two printers from Solartron are the ED.1035 direct printer and the ED.1036 register printer. The

former requires the input information to be maintained during the print cycle, whereas the latter stores each line of information until printed. The models have similar printing heads, which will print lines fourteen columns wide at faster than ten per second. The register printer can accept binary-coded decimal information (four-wire), or one out of *n* code (fifteen-wire) for each column.
Circle **No 556** on reply card

Ferrous-particle detector. A unit by Rapid Magnetic is intended for the extraction of minute ferrous particles from various fluids such as machine-tool coolants and lubricating oils. Permanent magnets are used to attract any magnetic particle, and phosphor-bronze filters both complement these and assist

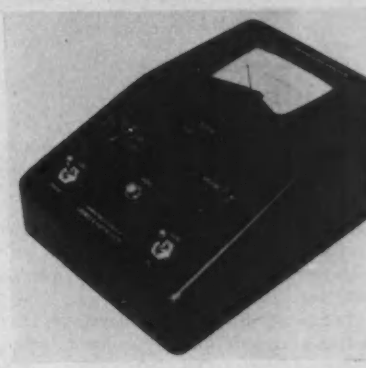


in the removal of any non-magnetic particles which may be present. Various models cover flow-rates from 200 to 3500 gal/h, and port-sizes are available from ½ to 1½in B.S.P.
Circle **No 555** on reply card

Neutron/gamma monitor. Plessey's portable 2NRM monitor uses separate detector probes to measure fast-neutron, thermal-neutron, and gamma radiation. It is designed to Admiralty specifications for measuring radiation in the vicinity of a propulsion reactor.
Circle **No 577** on reply card

Laboratory pumps by Jones and Stevens have corrosion resistant stainless-steel bodies, and are operated by continuously-rated single-phase induction motors. The P.30 will pump 2½ pints/min, with maximum height of water 4ft, and the P.50 is rated at 5 pints/min with maximum height of water 4ft 6in. The units weigh 22 and 27 ounces respectively, and operate from standard 230V a.c. mains; models for non-standard voltages may be supplied to order.
Circle **No 551** on reply card

Thermocouple amplifier. An instrument by Grundy is intended for measuring temperature rise above ambient in devices such as transistor heat-sinks and transformers; it includes a standard Chromel-Alumel ambient reference-junction. The unit may be operated from the mains, but contains a ten-hour capacity re-chargeable battery, which is charged during mains operation, or



when the unit is not in use for measurement but switched to the 'charge' position. Temperature ranges using Chromel-Alumel junctions are 0–10, 0–100, and 0–300°C. Circle **No 554** on reply card

Transformer clamps. Made by M.K.S. Nucleonics, C-core transformer clamps are claimed to eliminate bending of the core, and to locate and line the core up automatically. They will shortly be available in production quantities for both standard-size and other cores.
Circle **No 579** on reply card

PUBLICATIONS RECEIVED

Automatic and remote control. Proceedings of the First International Federation of Automatic Control—Moscow 1960. *Edited by* **J. F. Coales** *with* **J. R. Ragazzini** *and* **A. T. Fuller.** *Butterworths 1961. Four volumes, approximately 1000 pp. each. £12 per volume; £45 per set.* ★582

Automatic programming *by* **Richard Goodman.** *Pergamon Press. 1961. 394 pp. £3 10s.* ★583

Electronic digital computers *by* **G. D. Smirnov.** *Pergamon Press. 1961. 104 pp. £2 2s.* ★584

Computer control systems technology. *Edited by* **Cornelius T. Leondes.** *McGraw Hill Book Company Inc. 1961. 694 pp. £6 4s.* ★585

Programming and coding for automatic digital computers *by* **George W. Evans II** *and* **Clay L. Perry.** *McGraw Hill Book Company Inc. 1961. 249 pp. £3 14s.* ★586

The theory of Lebesgue measure and integration *by* **Stanislaus Hartman** *and* **Jan Mikusiński.** *Pergamon Press. 1961. 176 pp. £1 10s.* ★587

Report. The 1960 report of the Warren Spring Laboratory. *Published for D.S.I.R. by H.M.S.O. 25 pp. 3s.* ★588

Technology. The 1960/61 report of the National Council of Technological Awards. *Published by the Council. 37 pp.* ★589

Annual report. The second annual report, 1960–61, on the O.E.E.C. Dragon project, has been issued by the U.K.A.E.A. ★591

'Lead for radiation protection' is the title of an illustrated 18-page brochure from Associated Lead. ★592

The Omegatron, a special type of mass spectrometer, is the subject of D.E.G. report 327 (CA) from the U.K.A.E.A. ★593

Co-ordinate table. The Atlantic co-ordinate table, using Ferranti numerical positioning, is described in a brochure from Dowding and Doll. ★594

Solid-state circuit elements. Four plug-in modules by S.T.C. are described in an illustrated leaflet. ★595

Semi-conductor device guide: a leaflet by G.E.C. giving brief details of their current range. ★596

'It's cheaper by air' is the title of a B.O.A.C. booklet dealing with air cargo across the North Atlantic. ★597

Regulated power supplies are described in leaflets PS4/1/61 and PS5/1/61 from Dukes and Briggs. ★598

Automatic data-processing. The Kimball punched-card system is described in a leaflet from Monroe Calculating Machine. ★599

Review. Ferranti's activities during 1960–61 are reviewed in an illustrated booklet, list RFA/1. ★600

Pyrometer sheaths. A leaflet from Morgan Crucible, MRD1/61, describes their Metamic sheaths. ★601

Connectors. Plessey's UK-AN connectors are listed in detail in an illustrated brochure, No. 109/1. ★602

Radio aids flight trainer. Specification No. 60/Basic, available from Electronic Control Engineering, describes their flight trainer. ★603

Regulations for the electrical equipment of ships. The fourth edition is now available from the I.E.E. ★604

Resistors. Two reports from the E.R.A. are 'High stability carbon-film fixed resistors', ref. Z/T124, and 'The performance of insulated carbon-resin film resistors', ref. Z/T105. ★605

Precision instruments for d.c. measurement by Siemens are the subject of a leaflet from R. H. Cole. ★606

Design manual for Bellofram rolling diaphragms: a 17-page illustrated booklet from George Angus. ★607

Precision thermostats packaged to customers' requirements are described in leaflet PRET-26 from Metals and Controls (U.S.A.). ★608

An introduction to electronic computers, from I.C.T., describes in simplest terms the action and use of digital computers. ★609

Display system. A 12-page booklet from Philbrick Researches (U.S.A.) describes their model 5934 multi-channel calibrated display system. ★610

★ Circle the relevant number on the reply card facing page 160 for further information

Book Reviews

Amplifiers

Self-saturating magnetic amplifiers *by* **Gordon Lynn** *et al. McGraw Hill Publishing Co. Inc. 1960. 217* pp. *£3 2s.*

The rate of development of engineering techniques is such that the rapid communication of ideas poses a formidable problem. A work such as this, which seeks to combine an introduction to the subject with basic design considerations and a summary of standard practice, therefore fulfils an urgent need.

In dealing with fundamental concepts the main point established is that when a device depends for its action essentially on a non-linear characteristic no useful analysis can be made by attempting to linearize the characteristic. The chapter on basic material properties, which rightly includes discussion on silicon diodes and plate rectifiers, relates flux–m.m.f. characteristics to domain phenomena; later this is treated more fully in a section on magnetic material evaluation. The behaviour of amplifiers is developed from consideration of the Logan circuit, comparison with the Ramey amplifier, the effect of bias, and a study of bridge and doubler circuits. The concept of amplifiers as volt-second controlled devices merits a chapter, whilst a study of dynamic response presupposes a knowledge of feedback notation and theory. Design methods are centred round certain typical functional requirements. Each chapter is followed by an extensive bibliography.

One criticism is of the style—qualitative and quantitative reasoning are at times intermingled to such an extent that the reader may find himself trying to retain a mathematical concept while simultaneously searching back for a relevant wave-shape or diagram. This apart, the work is one which should find a worthy place in the technical literature for so long as such amplifiers are used in the field of control. W. CHELLINGSWORTH

Photo-conductivity

Photoconductivity of Solids *by* **Richard H. Bube.** *John Wiley & Sons Inc. 1960. 461 pp. £5 18s.*

The phenomenon of photo-conductivity, or change of electrical conductivity on exposure to radiation, has been known for nearly a hundred years, but it is only in the last decade that the subject has developed extensively, partly owing to the stimulus given to it by the extensive investigations of the properties of semiconductors, in particular germanium and silicon. This has led to new theories and new applications of photoconductivity (the use of lead sulphide cells, to quote but one case), and although there is a wide literature relating to photoconductivity (just over a thousand references are quoted in the book under review), there are very few books dealing exclusively with photo-conductivity. This volume is therefore particularly welcome in that it presents an up-to-date account of this phenomenon.

After an historical introduction, there is a short account of the band theory of solids and a preliminary discussion of electronic processes in crystals. Photo-conductive processes, including such factors as lifetime, capture cross-sections, trapping and recombination levels and simple models for photo-conductors, are considered, the preparation of single crystals and polycrystalline layers of photo-conductors is dealt with, and there is a good survey of the methods available, together with excellent references to the original literature. A chapter deals with the phenomena associated with connecting electrodes to specimens, and includes a description of space-charge-limited currents in the presence of ohmic contacts, discussing their effect on gain. 67 pages are devoted to photo-conductivity arising from imperfections, and include detailed work on impurity levels in germanium and silicon, III-V compounds, II-IV compounds and on crystal defects in ionic solids, germanium and silicon, and in sulphides, tellurides, selenides and oxides. A chapter is then devoted to energy bands in real crystals, including the determination of band gaps in real crystals and a discussion of optical transitions, and the next four chapters deal with free carrier scattering and mobility, traps and trapping, and recombination processes. Some theoretical aspects of photo-conductivity follow, in particular the mechanism of photo-conductivity in lead sulphide, theories suggested from the treatment of luminescent phenomena and a detailed analysis of some simpler models. The final chapter briefly covers related optical phenomena, such as the photo-voltaic effect and the photo-magneto-electric effect, and gives as well a short description of the measurement of lifetime and diffusion length.

At times the style of writing is unusual and new matter is introduced without adequate explanation. There is an irritating lack of systematization of units, particularly in chapter four. The production of the book is good, though it is not free from misprints.

In general this book represents a thorough survey of the subject, well referenced and containing a large amount of factual information on photo-conductors, and it is therefore valuable to have. It has been written not to popularize the subject, but for those actively interested in photo-conductive processes in solids, and will well repay detailed study by those who wish to know more about photo-conductivity. J. E. CAFFYN

Components

Electronic Tubes and Semiconductor Elements—Universal Vade-mecum, Volume 1 *by* **Piotr Mikołajczyk.** *Pergamon Press. 1960. 1213 pp. £7.*

This is a catalogue of valves and semiconductor elements manufactured all over the world. They are classified in 637 groups comprising valves and semiconductor elements of identical or similar characteristics. Volume I deals entirely with valves. Volume II, which is in preparation, is to deal with transistors, oscilloscopes, photo-emissive cells, magnetrons, klystrons, etc. The information available is given under the following headings:

- *i* Rated values of electrical parameters and relative service conditions
- *ii* Equivalents
- *iii* Connexion arrangements for the valve sockets
- *iv* Some characteristics of the valves, typical of each group
- *v* Operating conditions for the most up-to-date valves

To assist the user in making the correct choice of valves for a particular purpose, all the items have been additionally arranged according to their characteristics.

So far as British readers are concerned, the book is likely to be of particular value to designers concerned with anglicizing foreign equipment, and judged from this point of view it appears to be an excellent publication. However, valve hand-books must be up-to-date! British publications of this sort tend to take the form of a loose-leaf folder, and by this means new sheets can be added and sheets referring to obsolete items removed. In some cases annual changes might be of the order 10–15%, and so for the *Universal Vade-mecum* to be of any lasting value it must be kept up-to-date. Neither the author nor the publisher gives any hint as to how he proposes to deal with this problem. It would be possible, no doubt, to publish new entries in supplemental volumes issued every year, but the conventional bound form of the volume makes it less satisfactory than a loose-leaf system. DENIS TAYLOR